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TABLE OF CONTENTS ON PAGE 2

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CONTENTS FOR JULY, 1950

American Journal of Orthodontics

Original Articles

An Electromyographic Analysis of Certain Muscles Involved in Temporomandibular Movement. Robert Edison Moyers, D.D.S., M.S., Ph.D., Toronto, Ontario, Canada ---- 481

The Frankfort-Mandibular Plane Angle and the Facial Pattern. Ernest L. Johnson, D.D.S., F.A.C.D., San Francisco, Calif. ---- 516

Caries Incidence in Relation to Orthodontic Therapy. John J. Dolce, B.S., D.D.S., New York, N. Y. ---- 534

A Digest of "A Challenge to the Profession" ---- 546

Orthodontic Abstracts and Reviews

Orthodontic Abstracts and Reviews ---- 552

News and Notes

News and Notes ---- 557

Officers of Orthodontic Societies

Officers of Orthodontic Societies ---- 560

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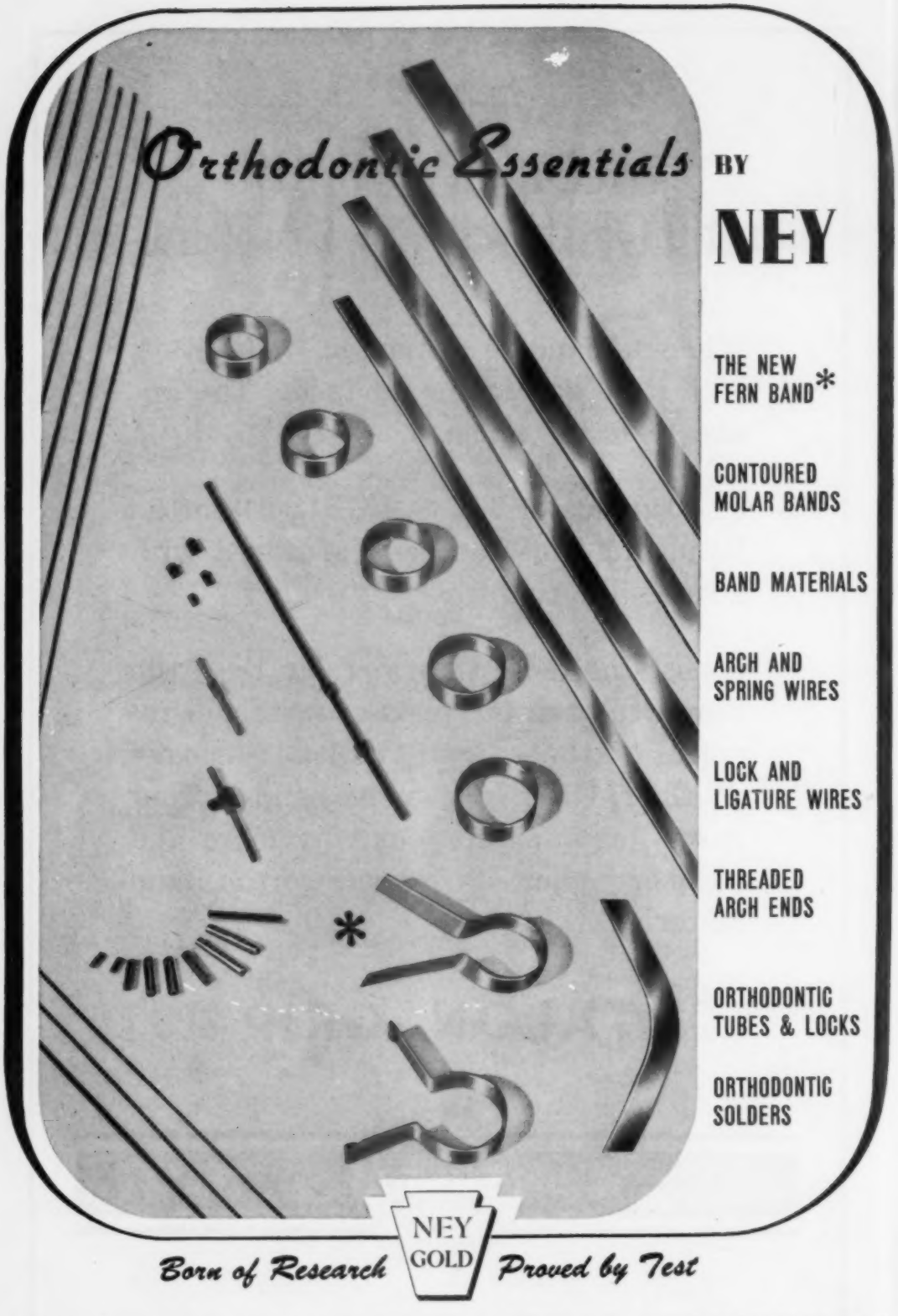

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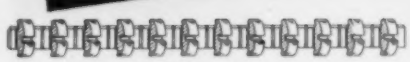

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VOL. 36 JULY, 1950 No. 7

Original Articles

AN ELECTROMYOGRAPHIC ANALYSIS OF CERTAIN MUSCLES INVOLVED IN TEMPOROMANDIBULAR MOVEMENT*

ROBERT EDISON MOYERS, D.D.S., M.S., PH.D.**
TORONTO, ONTARIO, CANADA

INTRODUCTION

THE temporomandibular articulation, often said to be one of the most complicated of human joints, has been a favorite for study by anatomists and physiologists. However, a thorough knowledge of the functioning of this articulation is of prime value, too, to the oral and maxillofacial surgeon, the otolaryngologist, the prosthodontist, and the orthodontist, who have made their contributions to the literature on the subject as well. As has usually been the case, the first studies made were based on observations from dissection. Such work assumes that since a muscle has a certain origin and insertion it must have a certain action. The great bulk of work done to date on the muscle action of the various human articulations has been this type of research. It suffers from two chief shortcomings: (a) it is not always possible to deduce from sheer observation the action of a muscle, (b) the very nature of dissecting, i.e., one muscle at a time, causes one to lose sight of the synergistic interplay of muscles around any joint.

Shapiro[68] studied the action of muscle of this articulation by direct electrical stimulation of the neuromuscular mechanism. These findings are based on the assumption that the induced stimulus is similar in strength, frequency, duration, and character to the normal efferent impulse. Further, no provision could be made for artificially inducing normal synergistic actions in muscle groups, since the cerebellum is involved in synergia. Thompson,[72] Higley,[33, 34] Higley and Logan,[35] Riesner,[61, 62] and many others studied the temporomandibular articulation by cephalostatic roentgenographic techniques. Klatsky[45]

This work was carried out under the auspices of the Department of Anatomy and the Department of Physiology, college of Medicine, State University of Iowa, Iowa City, Iowa.

This paper won first place in the Prize Essay Contest of the American Association of Orthodontists and was read at the annual meeting held in Chicago May 8-11, 1950.

*A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate College of the State University of Iowa, August, 1949.

**Professor and Head of the Department of Orthodontics, University of Toronto.

reported studies using cinefluoroscopic methods. Riesner, Corlin, and Eisner[63] recently reported a similar study using a technique involving the intramuscular injection of radiopaque dyes in conjunction with regular cinefluoroscopic methods in an attempt better to analyze the muscle action around the joint. Larson[46] approached the problem by using thermocouples to measure the rise in temperature of the various muscles as an indication of their activity. Among the more ingenious approaches toward understanding the dynamics of the temporomandibular joint was that of Lord,[49, 50] who constructed a model of the joint, attaching strings and pulleys in the proper places to simulate normal mandibular movements. In this manner he was able to make deductions as to the role of the separate muscles during the many mandibular movements.

Since the first reports in the literature concerning the phenomena of muscle action potentials (Piper[58] and Buchanan[12]) the method of electromyography has been used to learn more about the nature of contractile tissue, to study various aspects of muscle and neuromuscular pathology, and as a dynamic means of studying the function of various articulations. The successful use of electromyographic techniques in studying the action of the muscles of the shoulder joint (Inman, Saunders, and Abbott[43]), the wrist (Dempster and Finerty[18]), the hip (Jahnke[44]), and other similar studies naturally suggested the use of the method as a way of analyzing the action and function of the muscles of mastication. This study, then, is an electromyographic analysis of certain muscles involved in movement at the temporomandibular articulation.

METHODOLOGY

Recording Apparatus.—All of the records were taken with an Offner Type A six-channel electroencephalograph. This instrument was equipped with an audio unit, a six-element crystographic inkwriting recorder, and a synchronous controlled speed, motor driven paper feed. It provided good fidelity of frequencies up to 100 cycles per second. Except under unusual circumstances the "Lo" condenser setting was always used at 0.02 and the "Hi" condenser setting at 2. This allowed the regulation of condenser values so that the amplifier response was best in the range of frequencies observed in muscle contractions (Schwartz, Heath, and Hudson[66]). Six comparable records could be taken simultaneously at constant paper speeds of 0.5, 1.0, 2.5, 5.0, 10.0, or 25.0 cm./sec. A sensitivity of 10-12 mm./30 microvolts was found satisfactory. The short pens (2 3/4 inches) were used for most of the records, but the apparatus was equipped with the long pens during the first three months of the study. All records taken when the long pens were in use were corroborated or retaken later with the short pens, since the long pens led to unequal frequency response among the six channels. All subjects listed in Table I as having been observed for twelve months or less had no records taken when the long pens were in place on the apparatus.

Electrodes.—In the experiments being reported, potentials were recorded from individual muscles, from synergistic muscle groups, and from small

groups of motor units. Three types of electrodes were used: (a) surface electrodes consisting of a circular 3/8 inch silver disk used with electrode paste and employing colloidin as a dermal adhesive, (b) coaxial 27-gauge hypodermic needles with obturators (all of the obturator and needle were enameled except ½ mm. at the point, and the outside of the electrode was grounded), and (c) hypodermic or intestinal suture needles enameled but for ½ mm. exposed at the point. When using monopolar electrodes the difference in potential was recorded by the use of a common electrode in a less active area, e.g., the lobe of the ear. The choice of electrode is dependent upon the morphology of the muscle being studied and the particular problem at hand, e.g., the coaxial electrodes are better for the study of representative groups of motor units, the surface electrodes, for observing the action potentials of an entire muscle. All records were taken with the subject shielded within a grounded Faraday cage.

Fig. 1.—Placement of surface electrodes on the temporal muscle. Note that all three electrodes are equidistant from the common electrode on the lobe of the ear.

1. *Temporal muscle:* This muscle has been studied with as many as six surface electrodes, though three as shown in Fig. 1 were ordinarily used. Palpation of the muscle during mandibular movements revealed the anterior and posterior borders. One electrode was placed just inside each of these borders, the middle electrode being placed midway between them. This is an important precaution since if the electrode extends beyond the limits of the muscle it will pick up electroencephalographic changes in potential. Needle electrodes are not as efficacious in this instance since they markedly interfere with the action of the muscle. The availability of the muscle and the absence of underlying, superimposed, or adjacent muscle masses made this the easiest muscle on which to obtain routinely satisfactory readings.

2. *Masseter muscle:* The masseter may be approached with all three types of electrodes or combinations of them. Needle electrodes may be used provided care is taken to insert them parallel to the direction of the muscle fibers. This minimizes artifacts due to movement of the electrode. The surface electrodes were placed midway between the origin and insertion and equidistant from the anterior and posterior borders of the muscle with the teeth in occlusion.

Fig. 2.—Needle electrode in the internal pterygoid muscle. This electrode must run parallel to the fibers of the muscle to minimize trauma and displacement.

3. *Internal pterygoid muscle:* Surface electrodes failed to give constant worth-while readings; therefore, both types of needle electrodes were used. A strip of adhesive or Scotch tape was used to maintain the needle in position during the mandibular movements. Fig. 2 shows the position of such an electrode in the internal pterygoid muscle. In most cases 0.5 c.c. of 2 per cent procaine solution was introduced subcutaneously at the site of the puncture for the relief of pain. Care was taken to insure against any of the anesthetic agent entering the muscle fascia. The needle was inserted so that the exposed tip was a distance of from 1 to 1¼ inches from the gonion.

4. *External pterygoid muscle:* The most successful approach to this muscle involved the use of a 1½ inch 24-gauge intestinal suture needle with straight shaft and curved point, enameled throughout its length except for 0.5 mm. of the point. This electrode was inserted through the oral mucosa behind the maxillary tuberosity in a direction extending laterally, posteriorly, and superiorly from the tuberosity. After insertion, the particular channel being used was switched to the audio unit and the subject was instructed to open his mouth. If the peculiar crackling sound of muscle was clearly heard, the needle was known to be in position within the muscle. A piece of soft brass ligature wire encircling the last maxillary molar on the same side provided support for the needle during jaw movements.

5. *Suprahyoid muscles:* Both needle and surface electrodes were used, depending upon whether the action of a single muscle or a few motor units was under study. The anterior belly of the digastric muscle can ordinarily be palpated to allow placement of either the needle or surface electrodes. This was done with the teeth in occlusion. During movements of the mandible, the muscle moves so that the surface electrode may not be recording solely from the digastric and may be picking up other suprahyoids. When the exact nature of the digastric muscle contractions was being sought, it was necessary to rule out the possibility of other suprahyoid muscles recording through the electrode placed over the digastric. This was done by means of other surface electrodes placed in such a manner that the digastric could not record through them. In addition, a careful study of the digastric by means of needle electrodes, particularly the monopolar variety, was undertaken. A comparison of all the records thus obtained made it possible then to ascribe certain contraction potentials to the digastric and certain others as common to two or more suprahyoid muscles.

Subjects.—The subjects used in this study were selected on a basis of having a normal dentofacial growth pattern for their age and being free of temporomandibular articulatory difficulties. In all instances the occlusion of the teeth was normal.* Data are presented on thirty-one individuals, sixteen adults and fifteen children ranging in age from 3 years, 9 months upward. All were given routine dental examinations, and posteroanterior and lateral full-head roentgenograms were taken according to the cephalostatic technique of Higley.[32] No prosthetic, orthodontic, or other dental appliances were in place. Table I summarizes pertinent data with regard to the subjects of this study.

Recording Procedure.—After placement of the electrodes the subject was seated on a stool without back or headrest. All of the movements to be performed had been previously practiced in imitation of the writer. This procedure was repeated before any records were taken. The first electromyograms taken were those of "tonus," since this indicated the state of relaxation of the subject. Unrestricted movements were desired since nervousness and tensions produced action currents. Each mandibular movement was repeated

*The nine subjects in Table III are taken from another study (Moyers[58]). They do not constitute a part of the main group of subjects (Table I) used in this study.

at least ten times to enable taking records at various paper speeds and to insure constancy of results. The writer placed the electrodes and made the observations on all of the subjects except one, himself. A colleague trained in the technique placed the electrodes when the writer was the subject. Each subject was examined on at least three separate occasions. One subject has had temporomandibular electromyograms on twenty-seven different occasions. Eleven thousand five hundred three separate records from thirty-one subjects seen for one hundred ninety-five periods of observation over fifteen months' time are represented in this study.

TABLE I. DATA ON SUBJECTS OF THIS STUDY

	SUBJECT	AGE	SEX	PERIODS OF OBSERVATION	LENGTH OF TIME STUDIED (MONTHS)
1	JW	28	M.	5	8
2	WKH	31	M.	4	5
3	ROT	6 6/12	F.	10	14
4	KTL	8 4/12	F.	9	10
5	AL	11 7/12	M.	10	12
6	JOB	34	M.	6	4
7	LOW	39	M.	5	3
8	KLM	23	F.	4	5
9	DJS	22	F.	3	2
10	POK	4 4/12	F.	7	11
11	DAK	24	F.	4	4
12	PJM	27	M.	5	3
13*	REM	28	M.	27	15
14	DTM	7 4/12	M.	4	11
15	BLK	9 5/12	F.	7	10
16	MJM	8 2/12	F.	6	11
17	WRR	25	M.	5	4
18	TOS	31	M.	4	3
19	RTS	19	M.	7	6
20	PLC	3 9/12	F.	5	11
21	PLP	4 10/12	M.	6	9
22	JLH	11 1/12	F.	7	12
23	RGD	14 4/12	M.	6	8
24	RMS	10 1/12	F.	5	10
25	GRL	27 1/12	M.	4	4
26	JAM	28	M.	4	5
27	JMC	27	M.	5	5
28	JSM	5 1/12	F.	6	11
29	FES	7 5/12	M.	6	13
30	SES	8 3/12	F.	5	12
31	RWT	36	M.	4	3
				195	

Total male subjects, 18.
Total female subjects, 13.
*All readings on this subject were taken by Dr. John Whinnery.

RESULTS

Remarks Pertinent to Interpreting the Results of This Study.—Muscle contractions are accompanied by minute changes in electrical potential which, after much amplification, can be detected and recorded. If this recording is done on a moving surface, the potentials are recorded as a wave that is diphasic in character. The initial and main deflection is termed a spike. The continued contraction of a muscle is recorded as a series of spikes as different muscle units enter the contraction. An indication of the entrance of additional units

into the contraction is seen as an increase in frequency or number of spikes per second. Simultaneous contractions of several motor units may produce a single spike which is of greater amplitude than that of a single motor unit. This phenomenon results from summation.

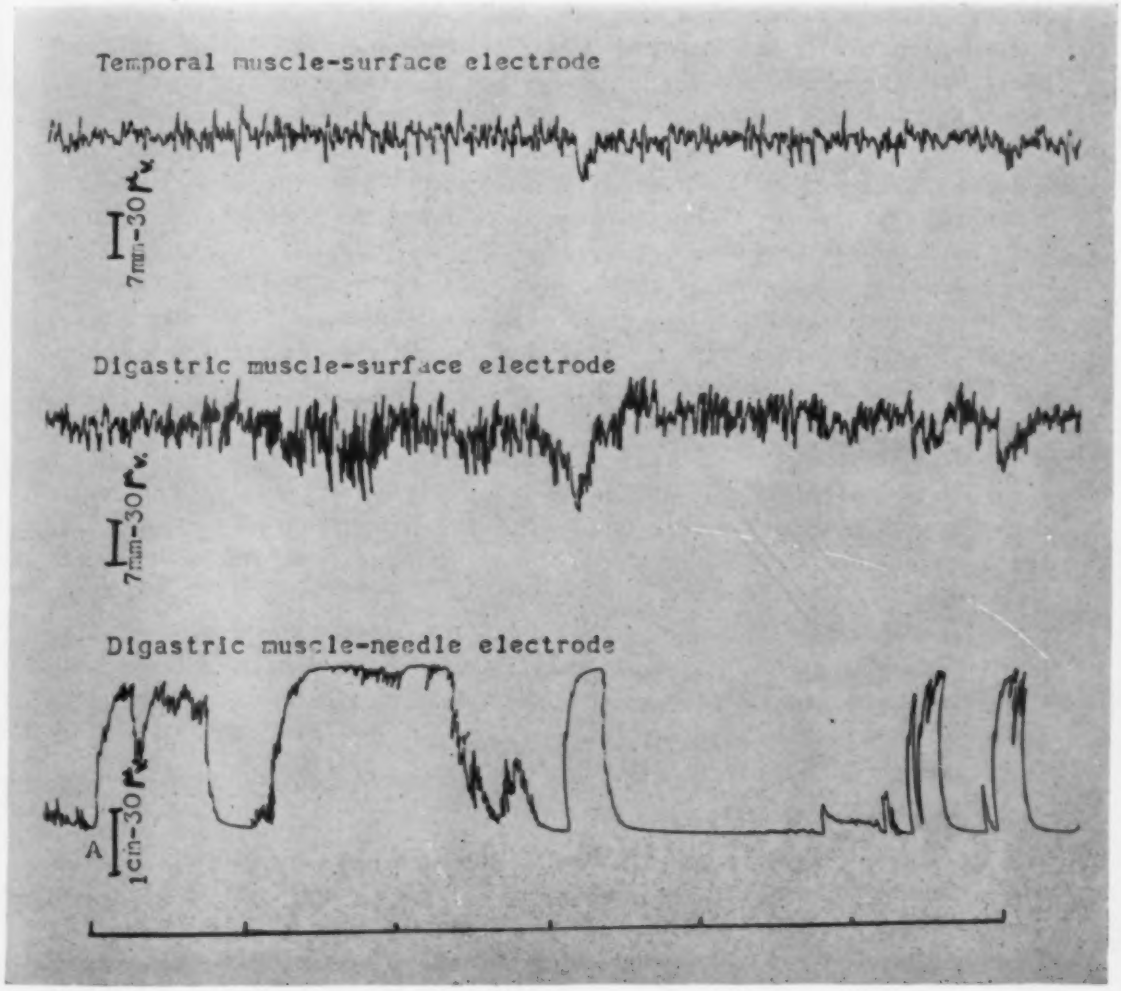

Fig. 3.—Comparison of coaxial needle electrode and surface electrodes from the same muscle.

This simultaneous recording was taken during mild contractions associated with mandibular depression. The gain is higher on the needle electrode channel. Time is shown as one-half second intervals. Note the many artifacts in the needle electrode record, due to movement of the needle, which do not appear in the recording from the surface electrode.

Electromyographic records serve as a key to the nature of muscle contractions. Most muscle physiologists agree that the amplitude of the spikes thus obtained is proportional to the strength of the contraction. It is also generally held that increases in frequency occur with increasing effort. This is in conformity with the principle that the strength of contraction of a total muscle is in proportion to the number of motor units in simultaneous activity. However, it was noted in this study that groups of motor units in close prox-

imity showed great variation in frequency. In fact, one small group of motor units might increase or decrease its frequency, or even stop entirely, quite independently of other units in the same muscle. This agrees with the generally held principles of the tetanic nature of the contraction of a muscle as a whole. Surface electrodes do not necessarily demonstrate any such similar changes in the entire muscle (Fig. 3). Denny-Brown[19, 21] reported quite the opposite, but Hoefer and Putnam[41] said: "Correspondingly, during sustained effort frequencies are not constant but either vary in some of the units or decrease and increase in others independently. . . . At times certain leads were not active at all, and other times they started to discharge without any perceptible change in the condition of the experiment." In the present study it was noted that the correlation between frequency of the small groups of motor units and strength of contraction seemed better during strong contractions. It was impossible to prove any relationship between these two during mild or gentle contractions (Fig. 3). This, too, is in corroboration with Hoefer and Putnam[41] who reported, ". . . the activity of the individual motor unit appears, therefore, to be irregular during mild effort."

This discussion points up the fact that a full knowledge of the nature of a muscle contraction during a given movement cannot be gained from a single electrode's recordings. The surface electrode may be reporting an apparently different picture than either the monopolar or coaxial needle electrodes. Thus, the observer must show care in interpreting readings from different types of electrodes.

Several workers, Adrian and Bronk,[1, 2] Bauwens,[4, 5] Cuthbert and Denslow,[17] Brazier, Watkins, and Michaelson[9] and Dunn, Bennett, and McIntyre,[23] discussed the relative merits of various types of electrodes. The choice lies solely in what is to be studied: the problem is to interpret correctly the different records from the several types.

Movements of the Mandible.—

Opening or mandibular depression: The first high amplitude action potentials are seen in the external pterygoid. They soon reach a maximal height and persist near this level until the movement is well completed (Fig. 4). Thirty-six records were available for analysis in which simultaneous activity of the digastric and external pterygoid was studied. In all instances, the external pterygoid records were obtained by means of needle electrodes and the anterior belly of the digastric was studied with surface type electrodes. The mean total time for this movement was 2.89 seconds (range, 0.80-4.84 seconds; S.D., 1.25; S.E. mean, 0.0536). The mean time of the digastric contraction was 1.41 seconds (range, 0.08-3.56 seconds; S.D., 1.088; S.E. mean, 0.0466). Extension of the head causes the digastric to begin its contractions sooner and thus to participate in the movement for a longer period of time. To a lesser extent this is true when the head is flexed. Forced mandibular depression, isometric contractions, brings the digastric into the action almost as soon as the external pterygoid. Table II summarizes the data with regard to the length of time the digastric is involved in mandibular depression under

varying conditions. When "splinting" (Magoun and Rhines[52]) is occurring, high amplitude spiking is seen in the digastric as soon as in the external pterygoid (See page 511). The late participation of the digastric occurs, perhaps, as an effort to retract the chin point as the jaw is depressed, for, according to our observations, slightly protracting the mandible will often decrease the height of the spikes from the digastric during depression. At the initiation of

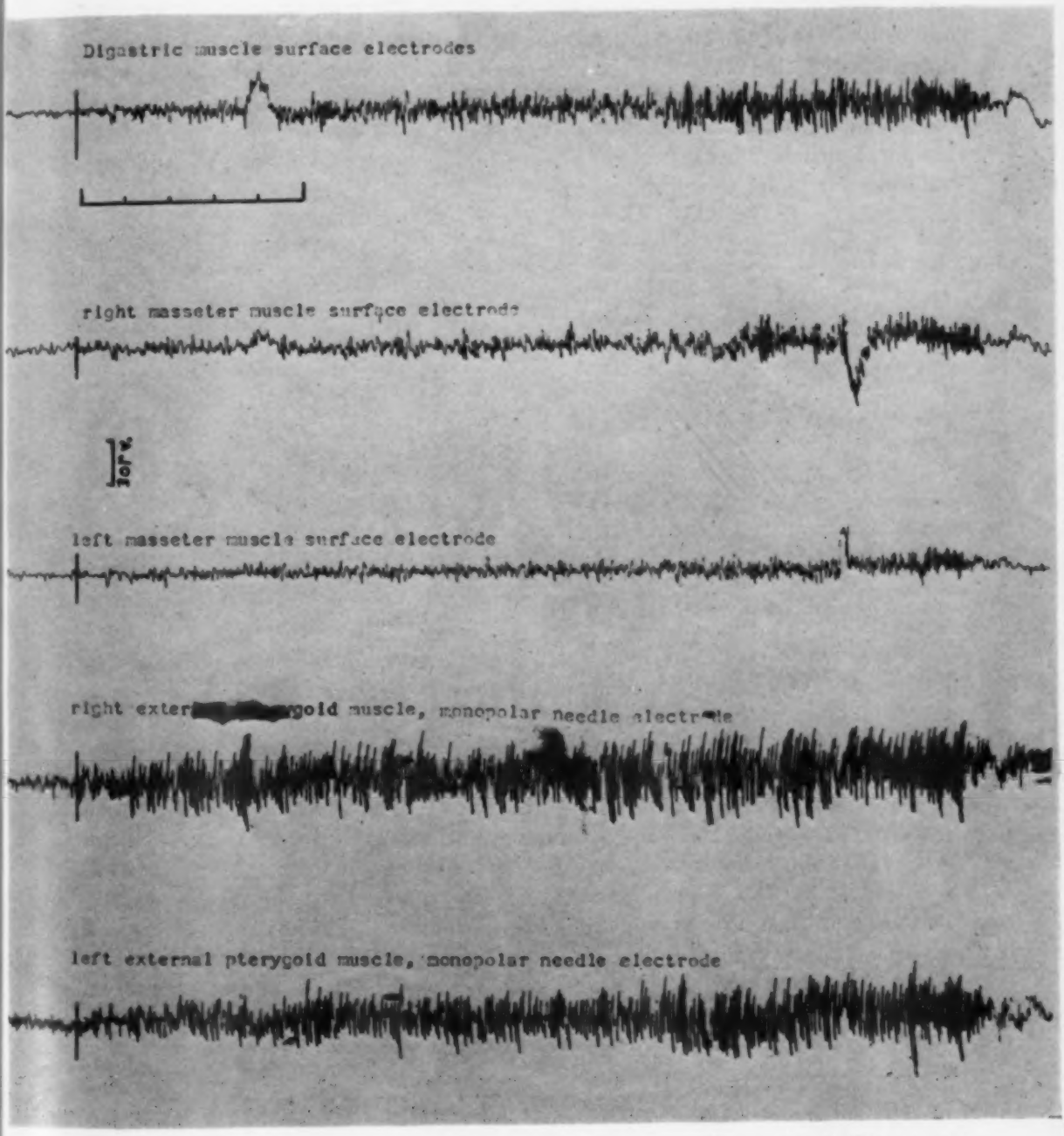
Digastric muscle surface electrodes
right masseter muscle surface electrode
left masseter muscle surface electrode
left external pterygoid muscle, monopolar needle electrode

Fig. 4.—Mandibular depression. Surface electrodes except monopolar needle electrodes in the external pterygoid muscle. Time equals one-fifth second intervals.

movement a small spike is consistently seen in some subjects (19.34 per cent, N = 31)* from the anterior fibers of the temporal muscle. This substantiates Bierman and Yamshon[7] who reported, "At the initiation of a movement, potentials can occur in the antagonists."

The combining of protractive movements with depression brings forth action potentials from the internal pterygoid, external pterygoid, the superficial layer of the masseter, and, in some cases (16.1 per cent, N = 81), the anterior fibers of the temporal muscle. Dissection of the temporal muscle has demonstrated that a few of the anterior fibers often take origin in the most lateral aspect of the supraorbital ridge. Fibers following such a course could conceivably produce these spikes. The spikes from the anterior fibers of the temporal muscle during protraction are far from a constant finding and may not have particular significance.

TABLE II. LENGTH OF TIME THE DIGASTRIC MUSCLE IS INVOLVED IN MANDIBULAR DEPRESSION

	MEAN TIME OF TOTAL CONTRACTION* (IN SECONDS)	MEAN DELAY BEFORE DIGASTRIC CONTRACTION BEGINS (IN SECONDS)	MEAN TIME OF DIGASTRIC CONTRACTION (IN SECONDS)
Normal depression (N-36)	2.89	1.48	1.41
Depression with head fully extended (N-21)	3.64	0.58	3.06
Depression with head half extended (N-24)	3.14	2.18	0.96
Depression with head fully flexed (N-16)	3.03	1.71	1.32
Forced depression isometric contractions (N-19)	3.98	0.20	3.78

*This was measured from the first muscle to show contractions until the movement was completed i.e., the disappearance of those contractions in the muscles. The external pterygoid was the first muscle to show contractions in all instances, and both the digastric and external pterygoid quit their contractions at almost the same time. This is because the movement is terminated by the elevation of the mandible.

Elevation of the mandible: The internal pterygoid, masseter, and temporal muscles all display high amplitude spiking during elevation. Numerous records were available for study (internal pterygoid, N = 91, masseter, N = 304, and temporal, N = 2112), and at no time did any of these three muscles fail to demonstrate marked increases in potential during elevation of the mandible. The height of the spikes is increased by the resistance offered by a bolus of food between the teeth. Combining protrusive movements with elevation enhances the spikes from the internal pterygoid and after the masseter (22.22 per cent, N = 27). It also elicits spiking routinely in the external pterygoid. By placing materials of varying consistency between the teeth the increased strength necessary to complete elevation can be demonstrated (compare Figs. 9 and 12). Repeated chewing on a tough piece of rubber causes tremorlike patterns from these muscles. A single extremely strong sustained isometric contraction in centric occlusion will provide a similar electromyographic record.

Lateral mandibular movements: The lateral movements of the lower jaw are described under several names in the literature: lateral excursive move-

*Figures thus placed in parentheses indicate the percentage of the time the observation occurs and the total number of records upon which the observation is based.

ments, trituration, abduction of the menton, and chewing motions. They are carried out by the same muscular mechanism and the name given to the movement is usually dependent upon the field of interest of the observer and the extent of the movement. Thus, "lateral excursive movements" is a term used by prosthodontists for an action which the anatomist might term "abduction of the menton." Trituration refers to small grinding movements less extensive in nature than what is usually thought of as lateral jaw movements. All lateral movements are brought about initially by the external and internal pterygoid muscles contracting unilaterally. The contraction of these muscles on one side moves the jaw toward the opposite side of the body (Fig. 5). Although spike potentials are seen in the suprahyoid and the masseter muscles, their role in the action is secondary (Figs. 5 and 21).

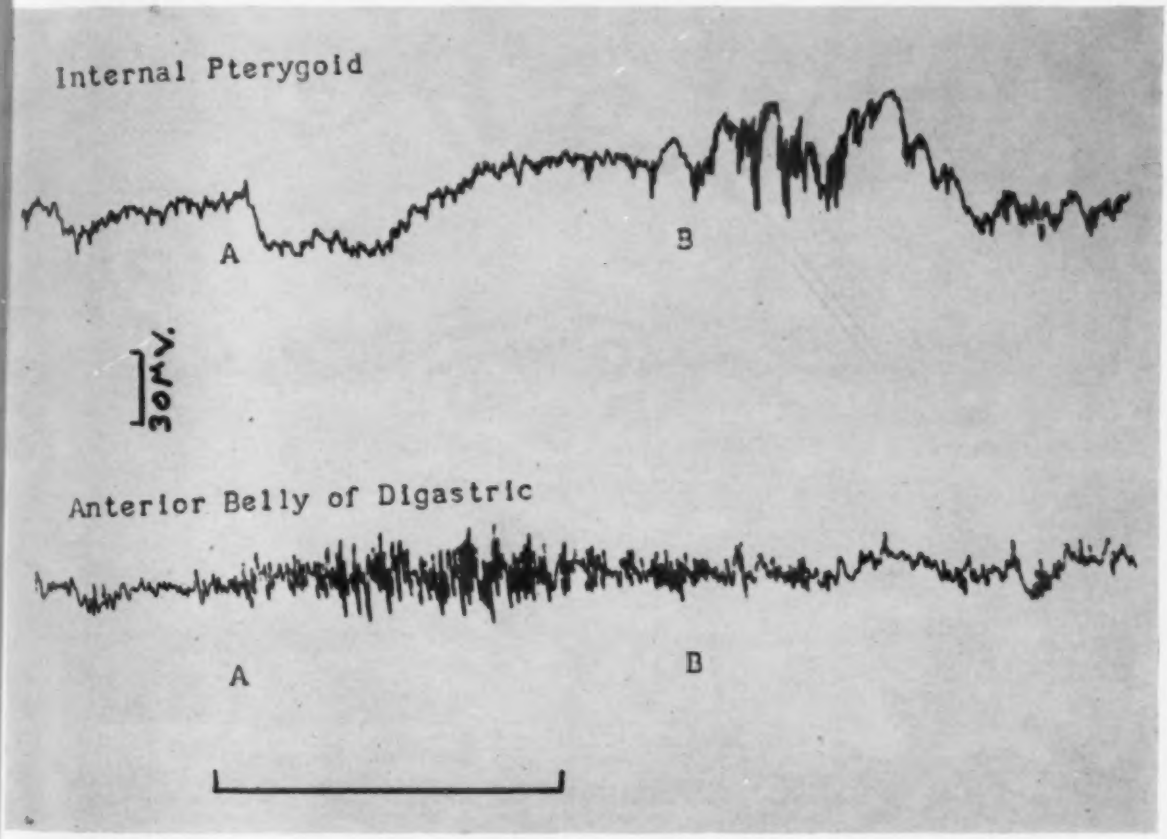

Fig. 5.—Abduction of the chin point.

Surface electrode on anterior belly of digastric muscle and monopolar needle electrode in the internal pterygoid muscle. Time is shown as one second. The electromyograms are from the muscles of the right side and the movement is toward the right. At *A* the right lateral movement is begun. Note that the internal pterygoid has little to do with this but that there are increases in both amplitude and frequency in the digastric muscle on the side toward which the chin is moving. At *B* the direction is reversed and the chin returns to the midline. Now the internal pterygoid takes on an active role and the spiking in the digastric is diminished.

Usually the chin point is retracted somewhat during lateral movements, which accounts for the strong spiking in the temporal muscle. Here, during lateral movements, the height of the spike increases as the electrode is moved posteriorly (Fig. 6). Unless the jaw is protruded during lateral movement, the

temporal muscle plays an important role in the action. Forty-nine electromyograms from eight different subjects were available in which simultaneous recordings from the external pterygoid, internal pterygoid, temporal, and digastric muscles of the same side were seen during lateral movements.

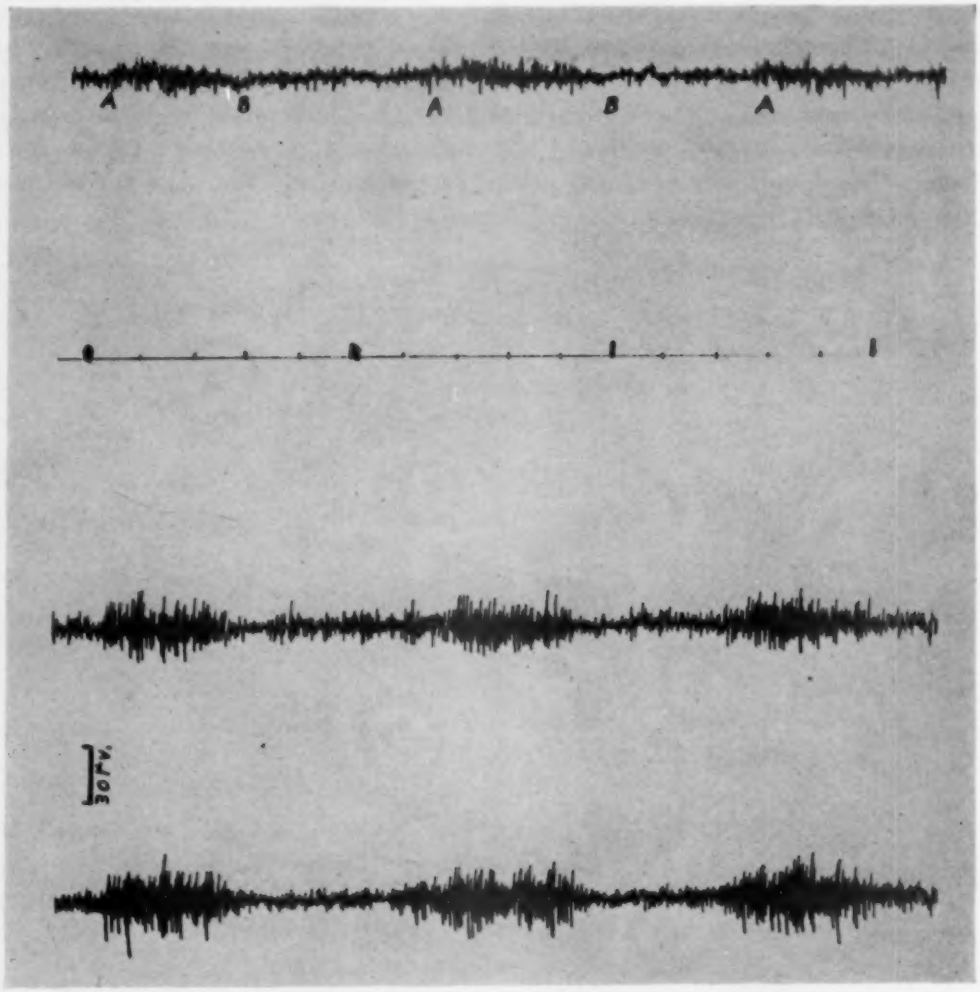

Fig. 6.—Temporal muscle during ipsilateral abduction of the chin point.

Surface electrodes. The top record is from the anterior fibers, the middle, from the middle fibers, and the bottom, from the posterior fibers. Three movements are shown to extreme lateral position and return to the midline. Time is shown as one-fifth second intervals. *A* marks the beginning of lateral movement, *B*, the start of the return to rest position. Note that the more posteriorly placed are the fibers the more active role they take in the movement.

Ninety-one readings from the external pterygoid alone, eighty-eight from the internal pterygoid alone, and two hundred thirty-five from the digastric alone during lateral movements were also available. Many attempts were made to obtain bilateral readings from both external pterygoid, both internal pterygoid, and both digastric muscles. With four needle electrodes in place the tendency for splinting to occur was so strong that little validity could be attached to the records thus obtained. Therefore, the statements made with regard to the

external and internal pterygoid muscles during lateral movements are based primarily on unilateral observations on both sides of the body. The temporal muscle's role in lateral movements was studied extensively, 1,704 readings on 31 subjects, but it, too, could not be studied well with more than two needle electrodes in place in other muscles. The lateral movements are brought about,

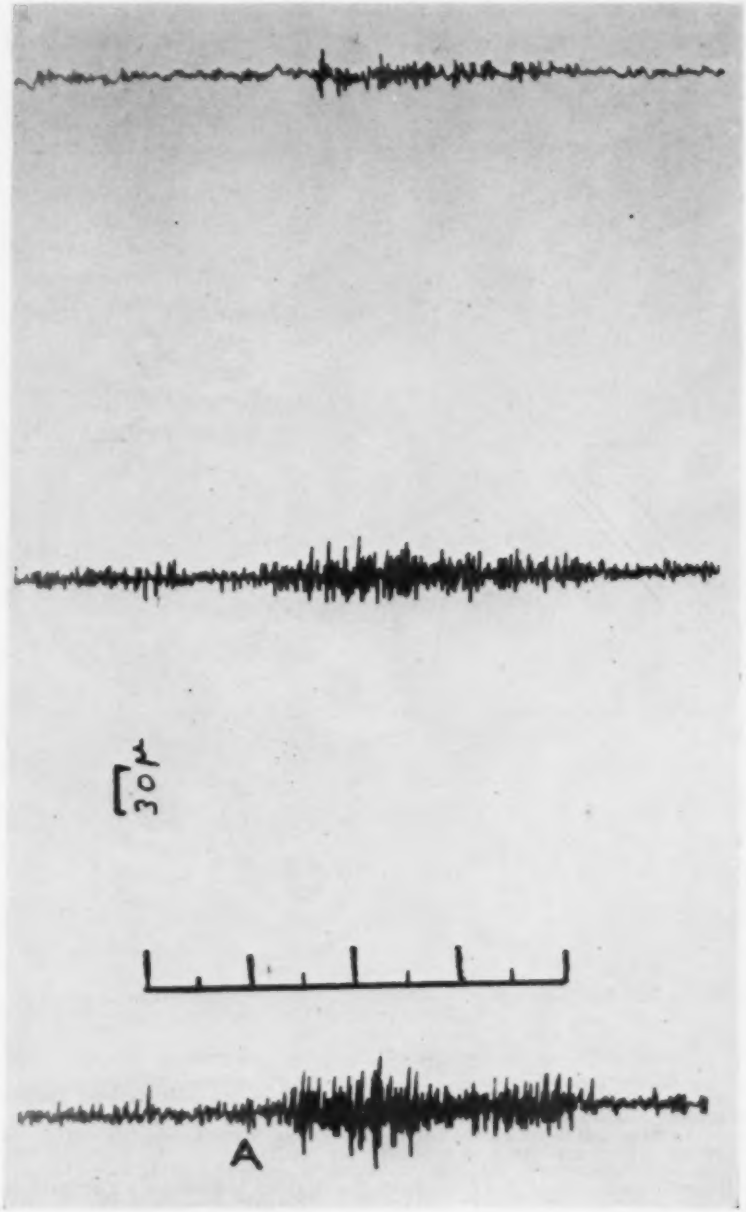

Fig. 7.—Retraction from a protracted position.

The top channel represents the anterior temporal fibers, the middle, the middle fibers, and the bottom, the posterior fibers. All electrodes are surface type. This movement was done slowly from a relaxed protracted position. Note the more dominant role of the posterior fibers. Time is indicated as one-half second intervals, i.e., four seconds are shown. *A* marks the initiation of movement.

then, by the combined contractions of the middle and posterior temporal fibers ipsilaterally and the external and internal pterygoid muscles contralaterally.

Protraction: During protratcion potentials are always demonstrated in the external (N = 92) and internal (N = 119) pterygoid muscles, and they seem to be almost exclusively responsible for this action. Spiking is often seen in the superficial layer of the masseter (31.56 per cent, N = 536) and the anterior fibers of the temporal muscles (5.22 per cent, N = 536). Also, there can be routinely observed spiking in the digastric, but this is passive in nature (Fig. 21).

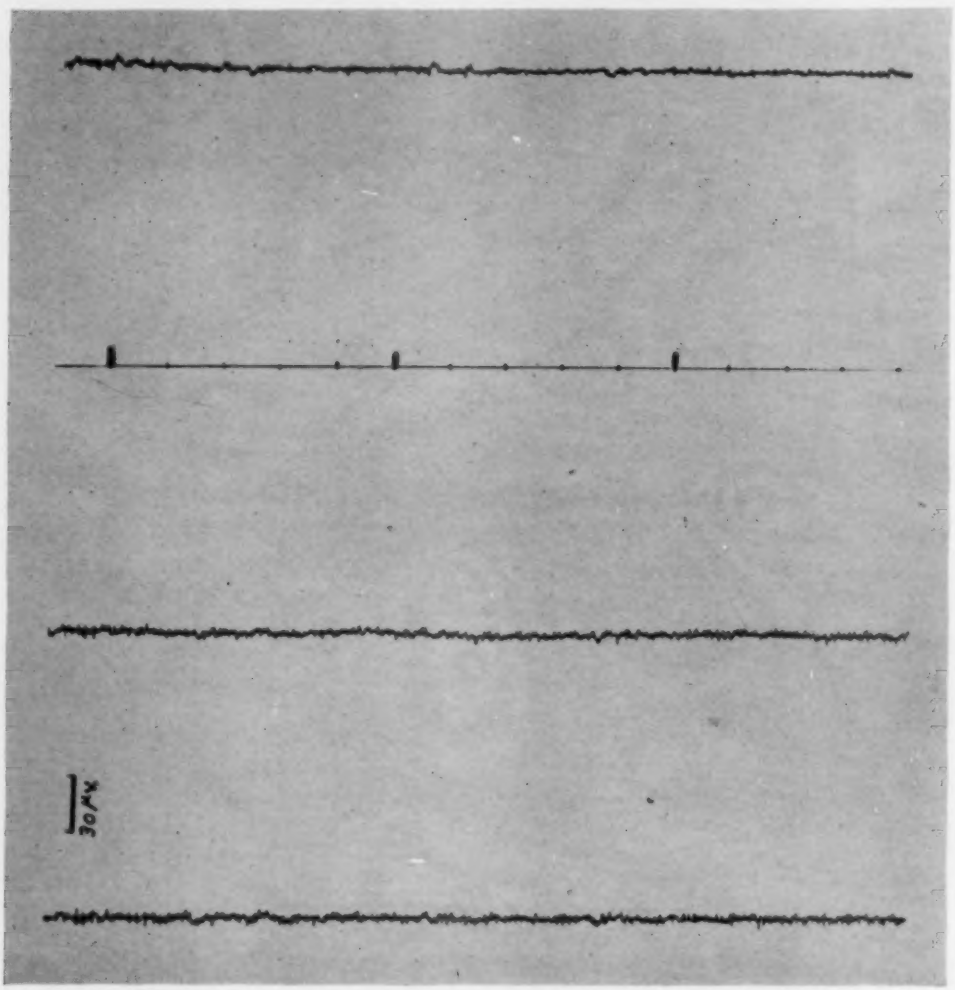

Fig. 8.—The temporal muscle with the mandible in physiologic rest position.

The anterior fibers are shown at the top, the middle, in the middle, and the posterior, at the bottom. Surface electrodes were used. Time, one-fifth second intervals. In persons with normal dentofacial structures there is a strong similarity among all parts of this muscle, both as to amplitude and frequency. The maintenance of mandibular posture is apparently shared equally by all parts of the temporal muscle in the normal individual. Compare this figure with the electromyographic records shown in Fig. 11. The latter were taken from a clinical case of mandibular retrogression.

Retraction: The muscle fibers involved in this movement depend to some extent upon the position of the mandible when the contractions are initiated. From rest position the middle and posterior fibers of the temporal muscle pri-

marily are involved (N = 514). Mandibular retraction from rest position is essentially an isometric contraction since the condyle can ordinarily be displaced posteriorly only a very small amount. Fig. 14 illustrates the action of the middle and posterior temporal fibers during retraction from physical rest position. Retractive contractions from a protracted position (N = 602) involve all parts of the temporal muscle, but the spikes from the middle and posterior

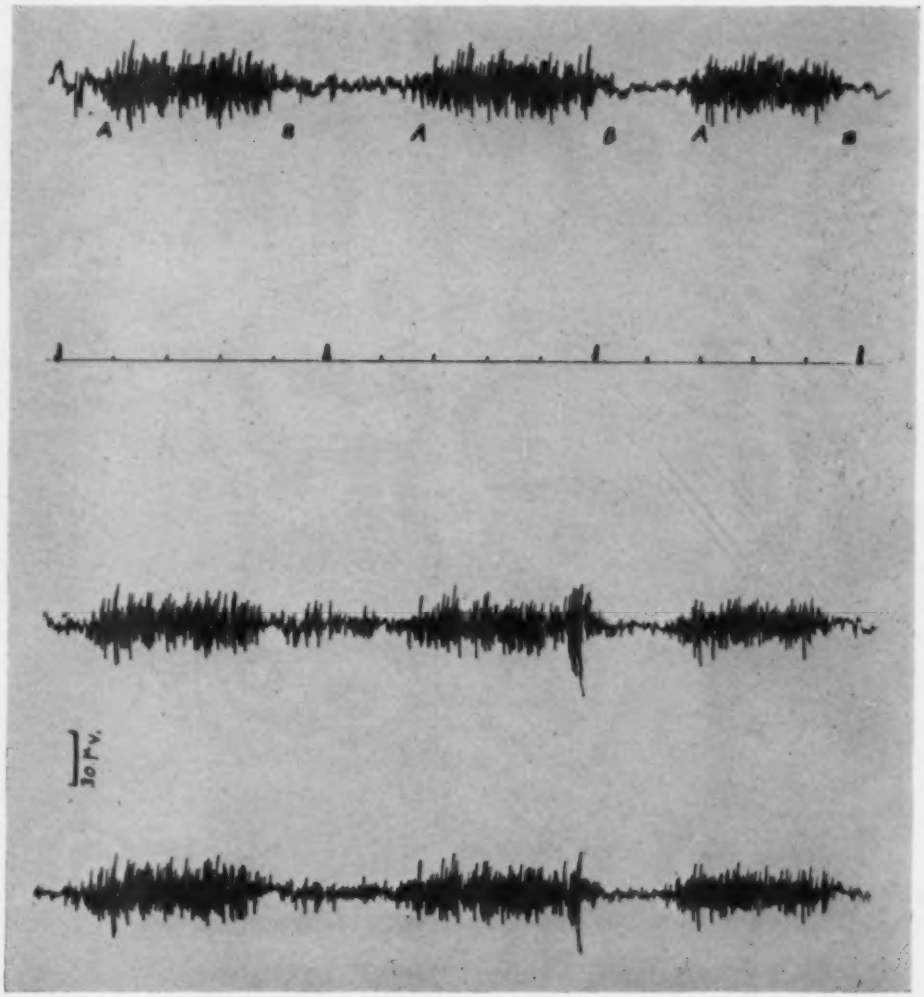

Fig. 9.—The temporal muscle during mandibular depression and elevation.

Surface electrodes, anterior fibers at the top, posterior at the bottom. In the normal individual all parts of the temporal muscle take part an equal amount during elevation of the mandible. Time is shown as one-fifth second intervals. *A*, Elevation; *B*, depression.

fibers show a greater amplitude (Fig. 7). Active contractions are seen in the anterior belly of the digastric muscle during all retractive movements (N = 291). The spikes are similar in amplitude and definition to those seen in the same muscle during the latter stages of mandibular depression. In some cases (4 per cent, N = 71) the masseter demonstrates marked spiking during retraction of the mandible. Its ordinary role, however, is rather passive in nature.

Electromyographic Analysis of Individual Muscles.—

Temporal muscle: Traditionally the action of this muscle is said to be that of elevation of the jaw. This is one of its primary duties, but it has other functions as well. Perhaps the most interesting finding on this muscle has been the fact that it presents great variation in its action and that this variation is directly related to certain dentofacial deformities of clinical orthodontic significance. This has been reported (Moyers[56]) and is illustrated in Figs. 8, 9, 10, and 11. Only the normal functioning of the muscle will be discussed here.

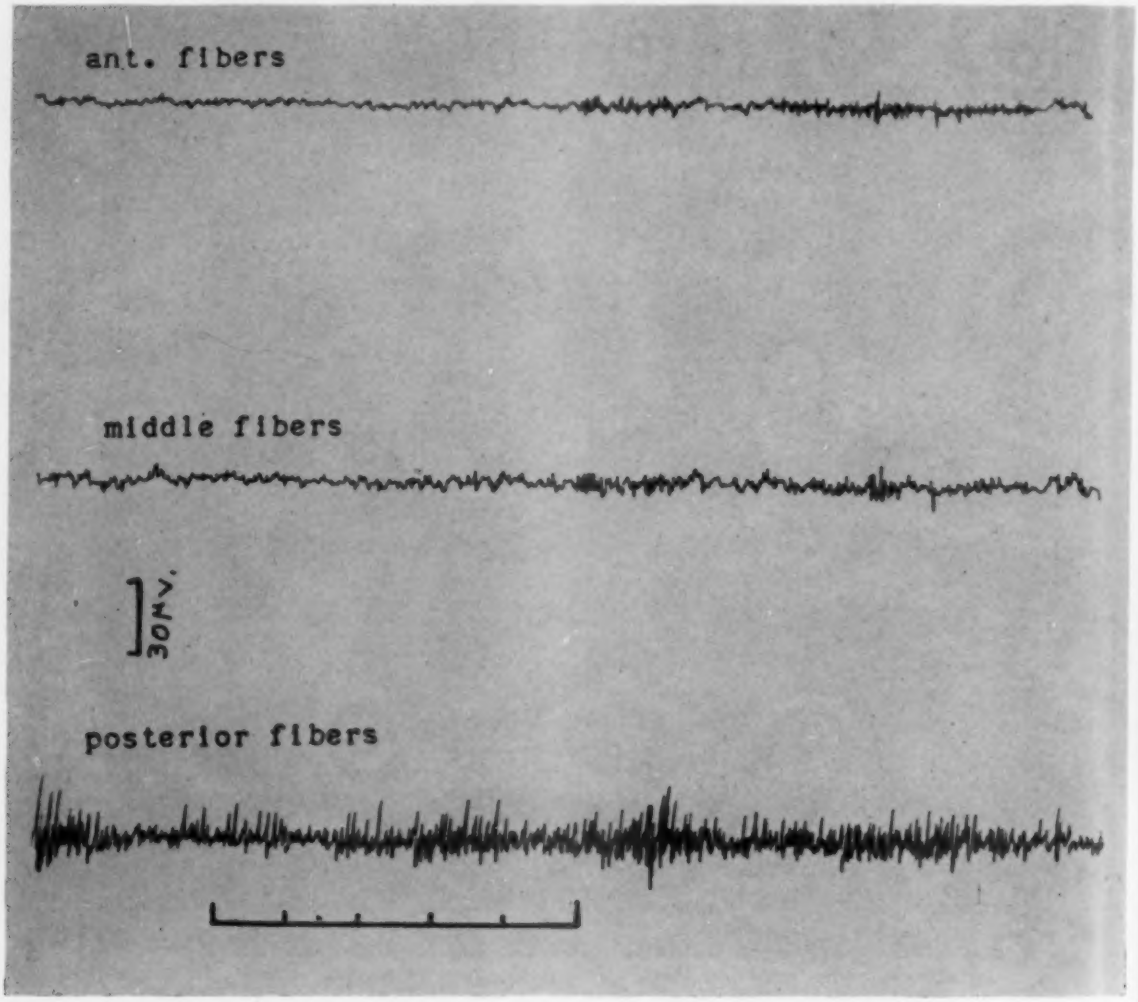

Fig. 10.—Physiologic rest position of the mandible in mandibular retrogression.

The imbalance of the various parts of the muscle in maintaining mandibular posture accounts for the retruded position of the mandible in some cases of total mandibular retrogression. Compare this record with the resting ("tonus") from the normal individual shown in Fig. 8. Time is shown as one-fifth second intervals.

As many as six electrodes have been used in studying this muscle, but only three were found routinely necessary. The break-up of the muscle into three separately acting component parts may be explained by the fact that the tem-

poral nerve is usually found in three branches. On the other hand, it may be that the direction of the muscle's fibers gives the answer: the anterior are vertical, the middle have an oblique course, and the posterior lie horizontally.

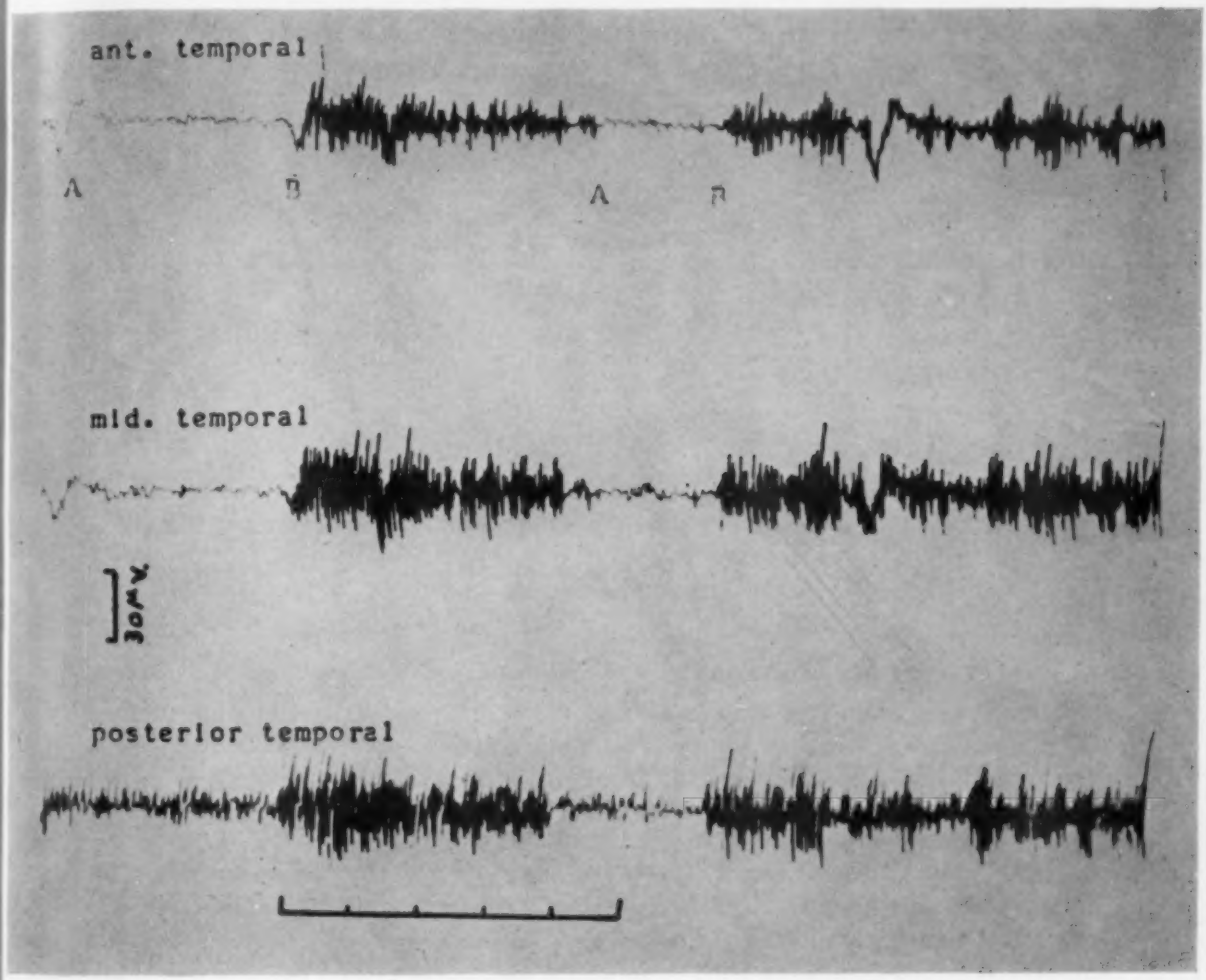

Fig. 11.—Mandibular depression and elevation in a case of total mandibular retrogression. Time is shown as one-fifth second intervals. *A*, Depression, *B*, elevation. This is the same patient shown in Fig. 10. Note the dominant role of the middle and posterior fibers of the temporal muscle during all aspects of these movements. Compare this record with that from a normal individual (Fig. 9). Of the 61 subjects thus far studied presenting mandibular retrogression, 8 per cent displayed a normal balance in all parts of the temporal muscle, 33 per cent showed dominance of the middle and posterior fibers (e.g., Fig. 21), and 54 per cent had exaggerated spiking in the posterior fibers only.

In any event, it behaves during certain movements as if it were in three distinct parts. The "tonus" displayed while maintaining the mandible in physiologic rest position is equal from all parts of the temporal muscle in the normal individual (Fig. 8) ($N = 621$). There is also a balance in the muscle during mandibular elevation, indicating that all parts of the muscle share equally in this function (Fig. 9) ($N = 1360$). This is not the case, however, in individuals with dentofacial deformities, and this lack of balance has been thought to be etiologic to certain of these clinical conditions (Moyers[56]) (Figs. 10 and 11).

During isometric contractions in physical rest position (centric occlusion) (N = 390), the spikes from the different parts of the muscle are similar in character and size (Fig. 12). The temporal muscle plays only a passive role in mandibular depression (N = 1360); however, it is a principal elevator of the mandible, and the low voltage spikes of passivity during depression are followed by strong spikes from all parts of the muscle when elevation is begun (Fig. 9).

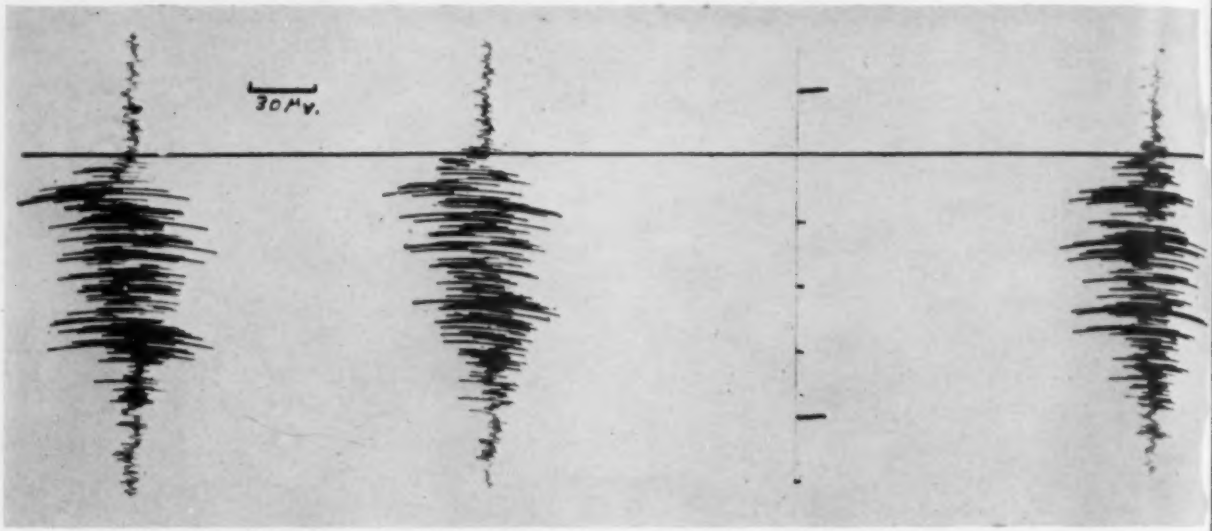

Fig. 12.—Isometric contractions of the temporal muscle while the mandible is in physical rest position.

Surface electrodes. The anterior fibers are to the right, the posterior, to the left. Note the similarity of all three records both as to frequency and amplitude. Time is shown as one-fifth second intervals. The horizontal line denotes the initiation of movement.

Although the anterior fibers sometimes demonstrate contractions prior to the other parts of the muscle (5.2 per cent, N = 1360, mean time, 0.17 second), the spikes from all positions of the muscle are similar in size and character. The temporal muscle has not often been ascribed an active role in abduction of the menton (the prosthodontists' lateral excursive movements). The size of the spike potential increases markedly toward the posterior on the side toward which the chin point is moving. The most posterior fibers play a dominant role in ipsilateral abductive mandibular movements (Fig. 6) (N = 852). During contralateral abductive movements the temporal muscle has only a very passive role (Fig. 13) (N = 852). Retraction of the mandible from a protruded position involves all parts of the muscle (Fig. 7) (N = 602); however, isometric retractive contractions while in physical rest evoke stronger action potentials from the posterior and middle fibers than the anterior (Fig. 14) (N = 211). In Fig. 15 is seen a typical picture of protraction of a forced nature from physiologic rest position. Note that although all parts of the muscle are involved in this contraction, the anterior fibers of the temporal muscle demonstrate the greatest spiking.

It has been found in this study that the function of the temporal muscle does not change appreciably with age, but temporary alterations in the electro-

myographic pattern are often seen in adolescents as temporomandibular adjustments to the arrival of new teeth. As the teeth settle into correct occlusion these ordinarily are lost and the original spike pattern once more appears. Figs. 16, 17, and 18 illustrate this phenomenon. Fig. 16 is the original record from a

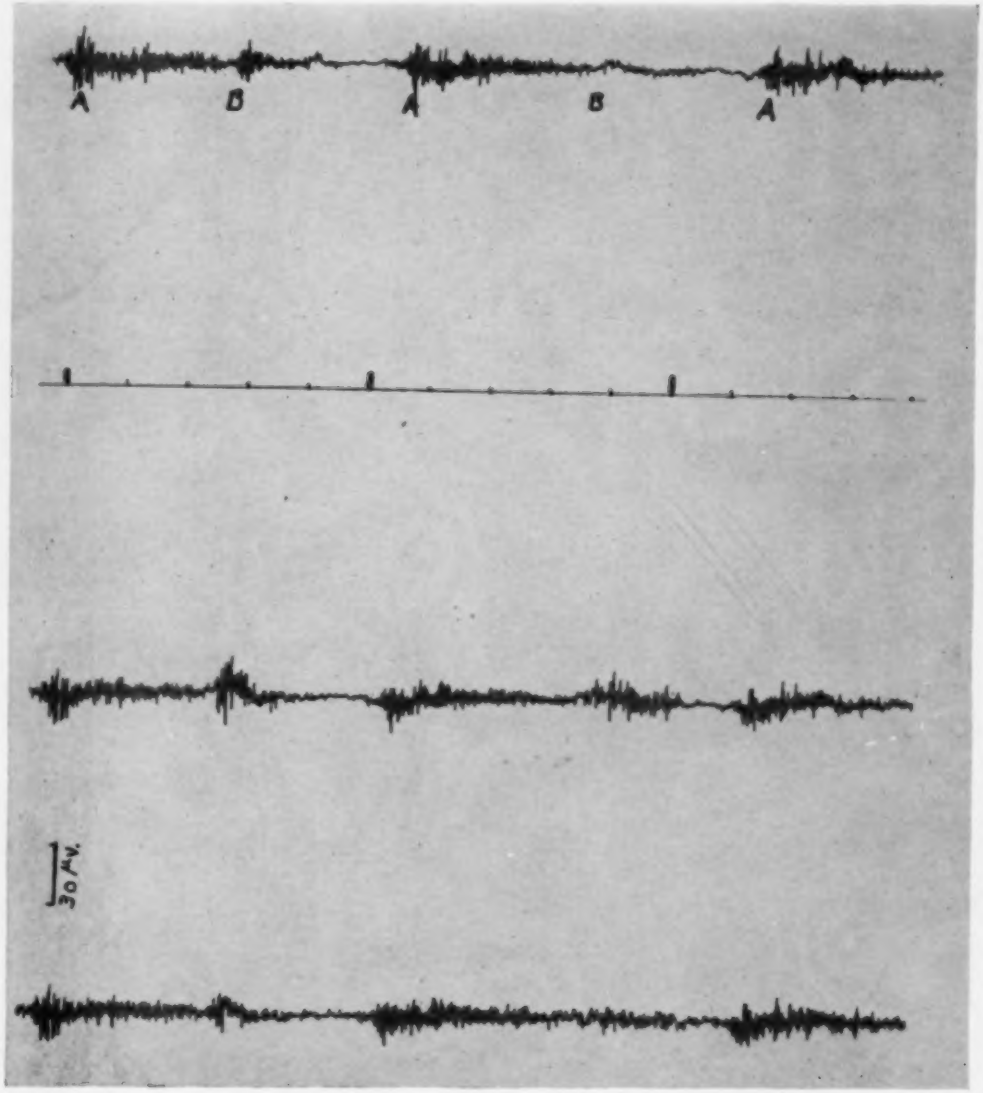

Fig. 13.—The temporal muscle during contralateral abductive movements of the mandible. The conditions for this reading are the same as for that shown in Fig. 6. Note that the temporal muscle has a less important role in contralateral than in ipsilateral abductive movements. The electrodes here were placed on the right muscle with the movements toward the left and returning to the midline. Time is shown as one-fifth second intervals. *A* marks the start of the contractions *returning the jaw to rest position.* At *B* the contralateral abductive movements are begun.

subject during mandibular elevation. At this time the subject still retained all of his deciduous molars. Fig. 17 shows a similar record from the same subject taken under comparable circumstances during the process of exfoliation of one of the mandibular deciduous molars. This tooth had necessitated an accommoda-

tive cross-bite which resulted in the mandible swinging markedly to one side immediately upon the initiation of mandibular elevation. Fig. 18 is another record from this subject after the eruption of the succeeding premolar. Note in this latter record that the right and left muscles seem more nearly in balance.

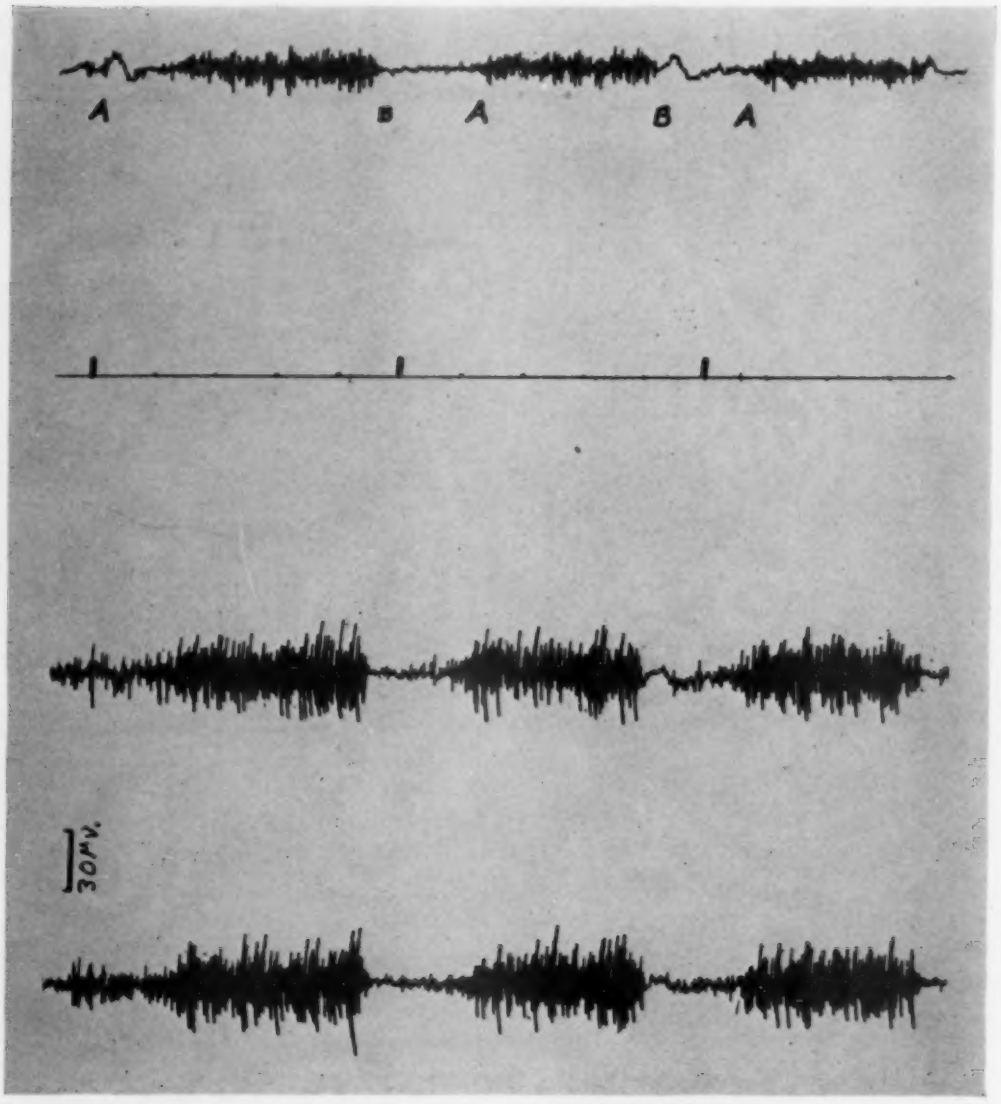

Fig. 14.—Mandibular retraction from physical rest (isometric contractions).

Time is shown as one-fifth second intervals. The anterior temporal fibers are at the top, the posterior, at the bottom. Surface electrodes were used. Note the more dominant role of the middle and posterior fibers. *A* marks the start of retroactive contractions; *B* designates the intervals of relaxation between efforts.

Table III presents data from nine subjects in whom these temporary changes in closure contraction pattern were observed. These nine subjects are not a part of the larger group studied for the rest of this project (Table I).

Masseter muscle: The primary function of the masseter is to aid in mandibular elevation (Fig. 19). It assumes a more dominant role if the mandible is

TABLE III. DATA ON SUBJECTS STUDIED WITH REGARD TO CHANGES IN CLOSURE CONTRACTION PATTERN

SUBJECT	AGE AT FIRST READING	AGE WHEN THE CHANGES APPEARED	AGE AT FINAL READING	TEETH INVOLVED
ROT	6 6/12	6 8/12	7 5/12	Maxillary right central incisor
KTL	8 4/12	8 11/12	9 2/12	Mandibular left first deciduous molar
AL	11 7/12	12 4/12	12 7/12	Both premolars in all quadrants
DTM	7 4/12	7 8/12	8 3/12	Maxillary central incisors
BLK	9 5/12	9 9/12	10 1/12	Maxillary right first deciduous molar
MJM	8 2/12	8 9/12	9 1/12	Mandibular right deciduous cuspid
JLH	11 1/12	11 7/12	12 1/12	All permanent second molars
RMS	10 1/12	10 9/12	10 11/12	Maxillary first premolars and second molars
SES	8 3/12	9 1/12	9 3/12	Mandibular right deciduous molar

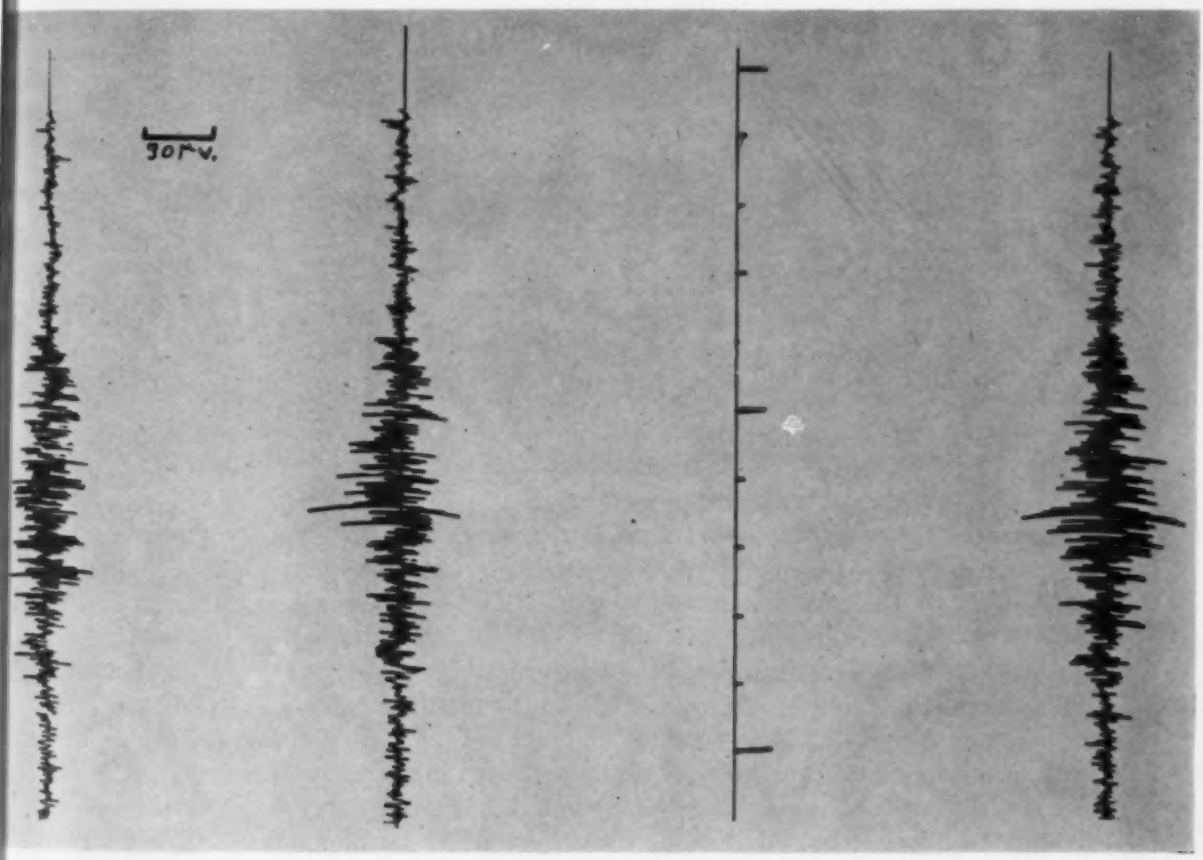

Fig. 15.—Forced protraction from physiologic rest.

Anterior temporal fibers are on the right; the posterior fibers are on the left. Surface electrodes were used. All parts of the muscle are involved in these strong contractions, but the anterior fibers show the greatest amplitude. Time is shown as one-fifth second intervals.

being protruded during elevation (N = 29). The masseter may participate in simple protraction (31.6 per cent, N = 536), but follows a passive role in retraction (N = 71) and depression (N = 130). During trituration, abduction of the menton, and other lateral movements, it does not play a dominant part in the action, yet the electromyograms are not those of sheer passivity either (N = 192).

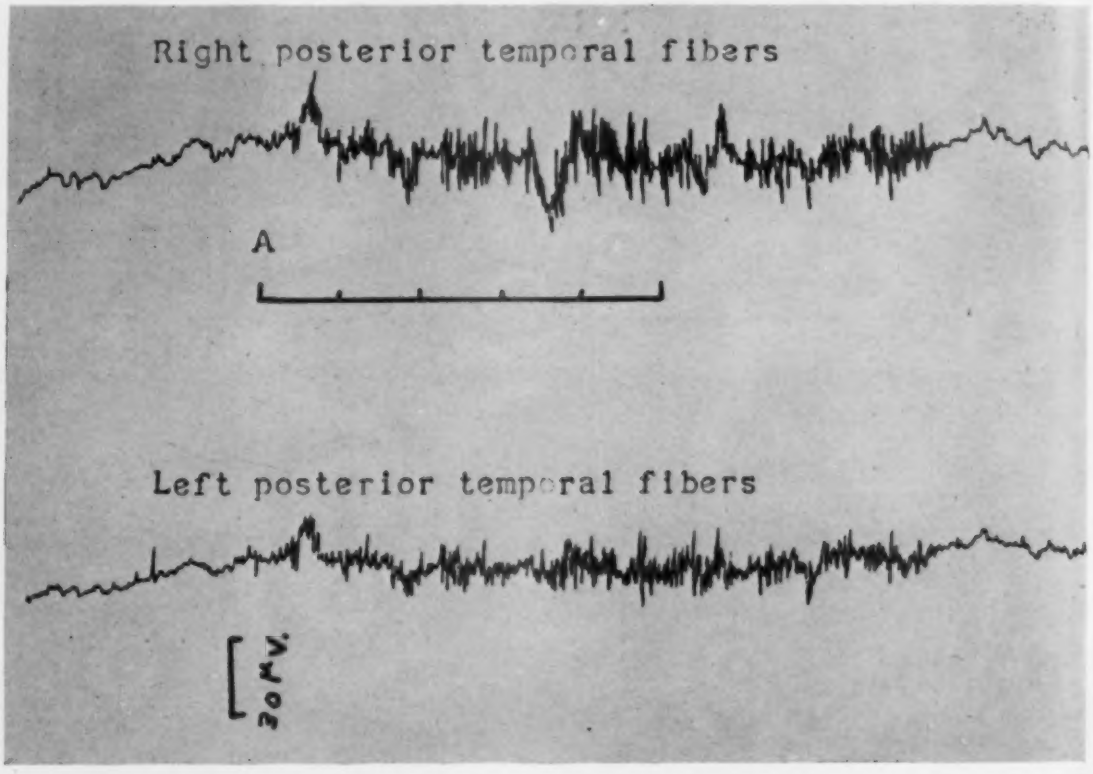

Fig. 16.—The temporal muscle prior to changes due to the exfoliation of deciduous teeth (mandibular elevation). Time is shown as one-fifth second intervals. *A* marks the start of movement. Surface electrodes were used.

Internal pterygoid muscle: The internal pterygoid is the third of the mandibular elevators. During simple protraction, strong spike potentials originate in both internal pterygoid muscles (N = 91). These decrease slightly if the mandible is depressed while being protracted (N = 19). Unilateral contractions of this muscle result in contralateral abduction of the chin point (Fig. 5). It joins the external pterygoid of the same side and the temporal muscle of the opposite side in this movement. The internal pterygoid is the more dominant if the lateral movement has a protrusive aspect as well, but in retractive movements during abduction the internal pterygoid assumes a less important role. For obvious anatomic reasons it has no dynamic role in retraction or mandibular depression.

Perhaps its most common task is that of lateral shifting of the jaws and the rotary movements associated with chewing. Alternating spike potentials are generated in the internal pterygoid muscles as the mandible moves from one side to the other (Fig. 20).

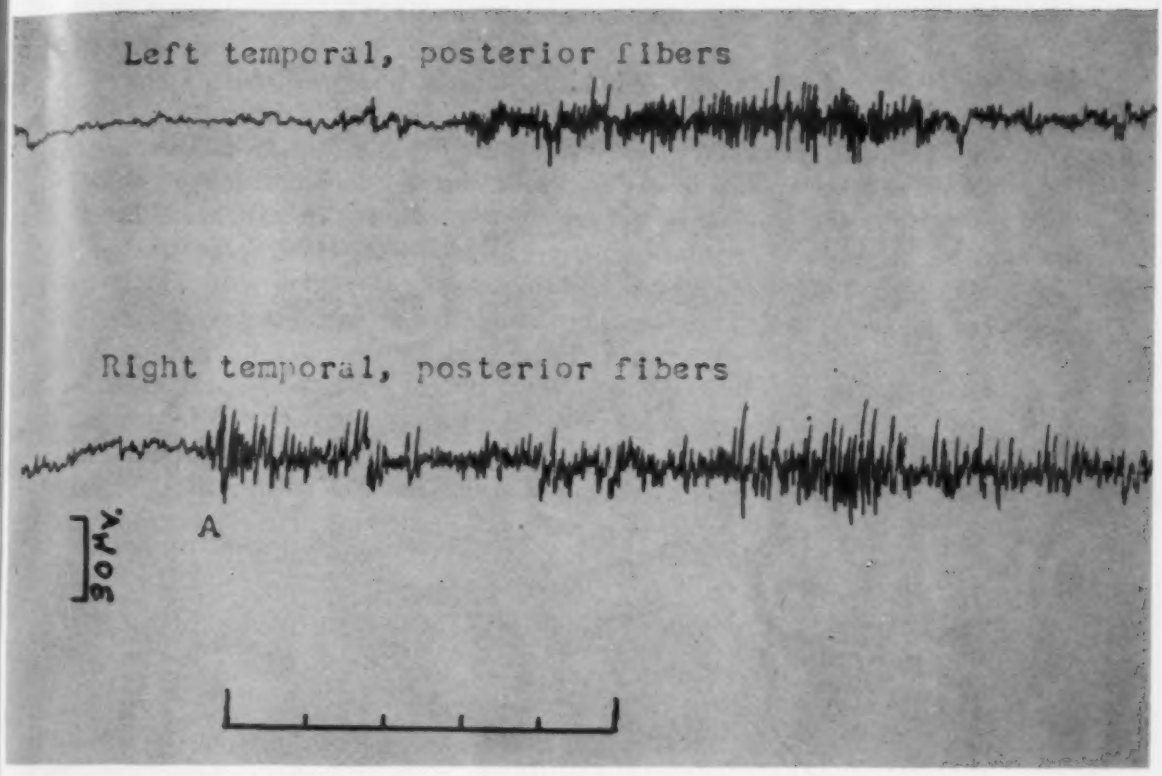

Fig. 17.—Changes in the temporal muscles' contraction pattern during the exfoliation of of teeth (mandibular elevation).

Time is shown as one-fifth second intervals. Surface electrodes were used. *A* marks the initiation of movement. Note that in this figure the *left* muscle is at the top of the figure. Compare this record with Figs. 16 and 18 which are from the same subject prior to and after this record.

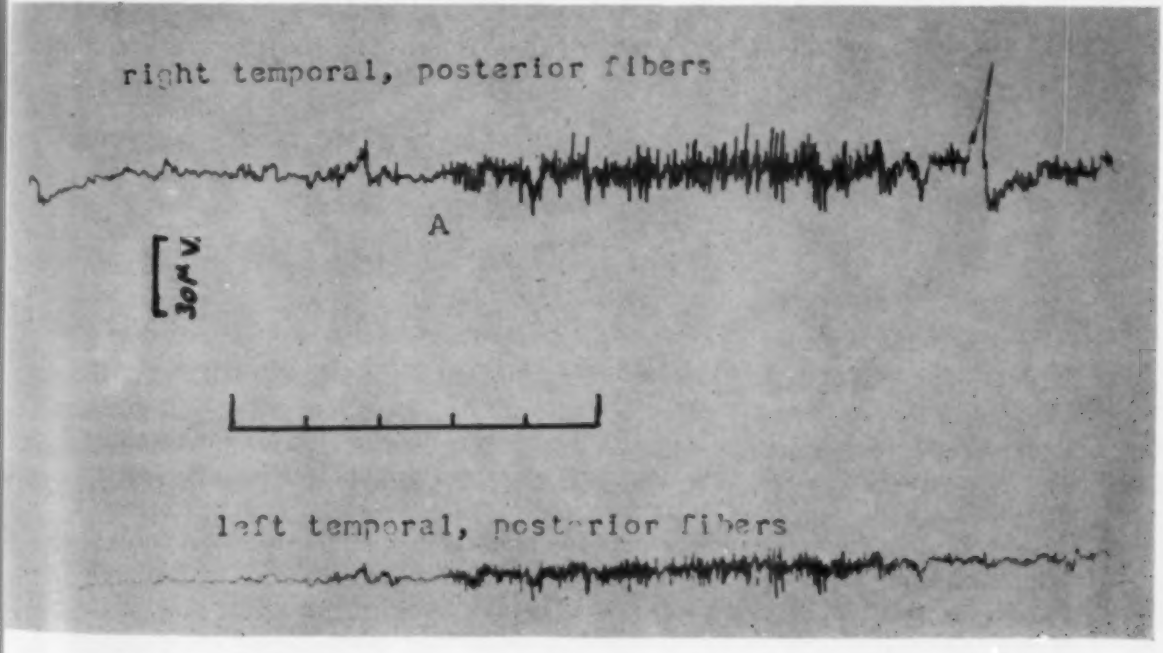

Fig. 18.—The temporal muscles after the disappearance of changes in contraction patterns due to the exfoliation of teeth.

Time is shown as one-fifth second intervals. Surface electrodes were used. *A* marks the initiation of movement. Compare this reading with Figs. 16 and 17.

External pterygoid muscle: While the internal pterygoid muscles and, to some extent, the masseter protract the mandible, their attachments are at the inferior border of the bone and would result in a rotating action around a condylar axis were it not for the external pterygoid muscle. This muscle's principal tasks appear to be the drawing forward of the meniscus and condyle head. Both the condylar process and articular disc must be moved anteriorly in protraction, depression, and lateral movements. During mandibular depression the first high amplitude spike potentials seen are those in the external pterygoid muscle (Fig. 4). This muscle reaches its maximal contraction prior to others involved in depression. However, its action persists for as long a period of time. During normal mandibular depression the external pterygoid was observed to demonstrate high amplitude contractions prior to any other muscles involved in the movement. It precedes the digastric by a mean time of 1.48 seconds. This amount of precedence is diminished if the head is extended or if the opening is of a forced nature (Table II).

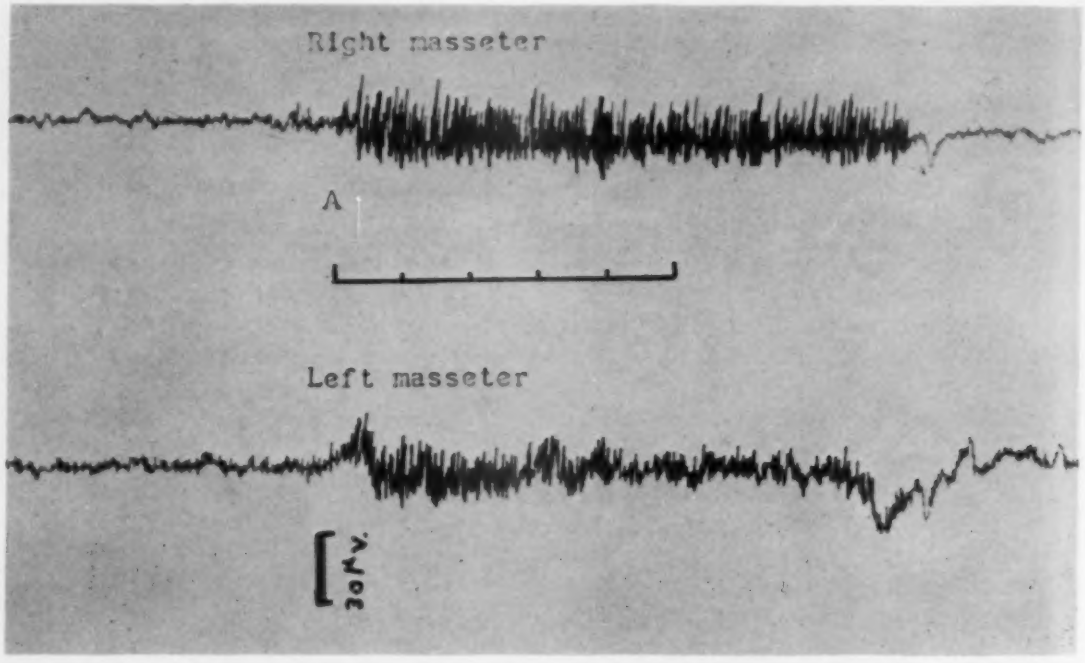

Fig. 19.—The masseter muscle during mandibular elevation. Surface electrodes. Time is shown as one-fifth second intervals. *A* marks the start of the movement.

Although attempts were made to break down the complicated action potential pattern into component parts, each of which might be associated with a separate part of the movement, they were without success. So synchronous is the action of the muscle that one gets the picture of a single sustained contraction accounting for both the drawing forward and depression of the condyle. The spikes are so strong and coincide so accurately with the actual movements of the jaw that one is forced to the conclusion that the external pterygoid is directly concerned at all times with this action. The muscle is involved in the

various lateral movements in much the same fashion as the internal pterygoid, except that the external pterygoid shows stronger spikes when the mandible is being depressed during abduction. Alternating contractions occur in the external pterygoid muscles during trituration or chewing movements since, when acting unilaterally, it draws the mandible to the opposite side of the body. Again

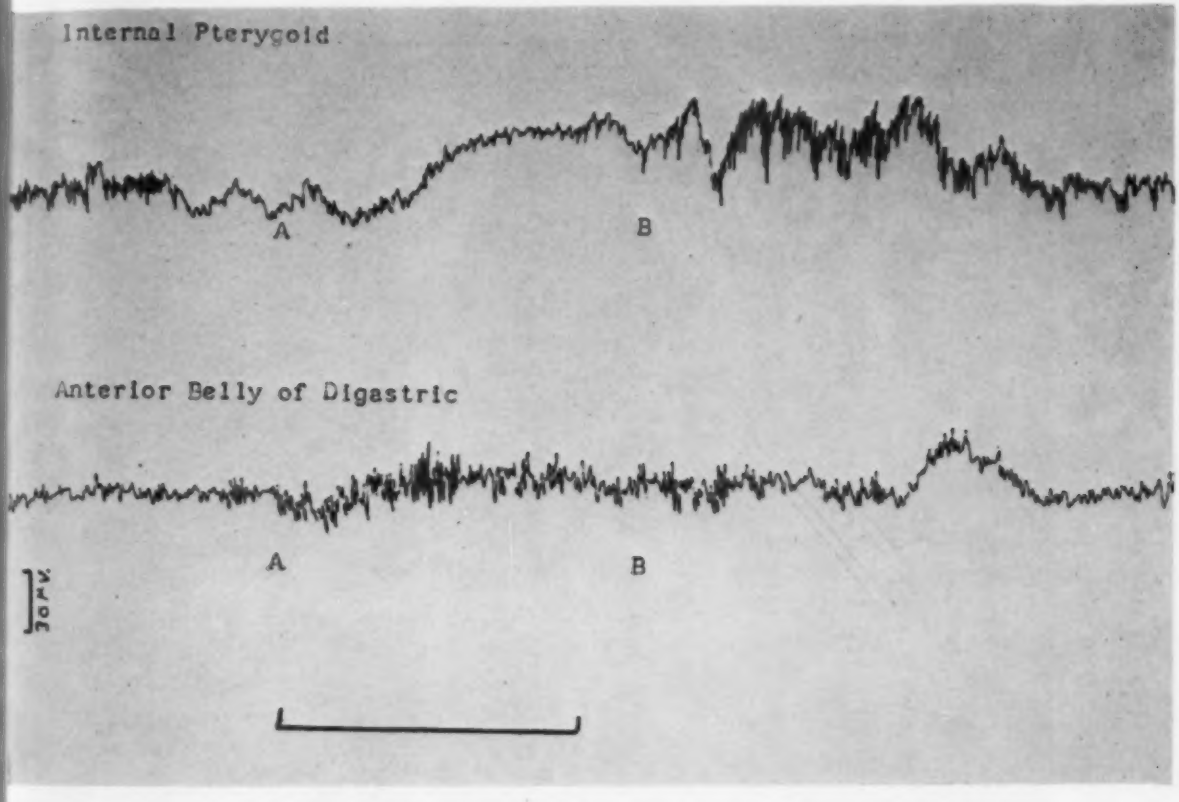

Fig. 20.—The internal pterygoid muscles during right and left lateral movements.

Readings from muscles of the right side; monopolar needle electrode in the internal pterygoid and a surface electrode on the anterior belly of the digastric. *A* marks the start of movements to the right and *B* of movements to the left. Note that the internal pterygoid plays a more active role in contralateral movements, the digastric in ipsilateral movements. Compare this with Fig. 5 where the mandible was returned to the midline only. Time shown as one second.

in protraction this muscle plays a dominant role, but it must be joined by the internal pterygoid and the masseter, or the contraction would result in opening of the jaws. During depression these latter two are passive and allow the mandible to be opened, but when they contract a forward and upward component is introduced which overcomes the tendency for depression to occur. For anatomic reasons the external pterygoid is not involved in retraction.

Suprahyoid muscles: These muscles are not correctly a part of the temporomandibular musculature, but they have been designated as movers of the articulation so frequently that their study was undertaken. No attempt was made to ascertain all of their functions; only their possible role in actual mandibular

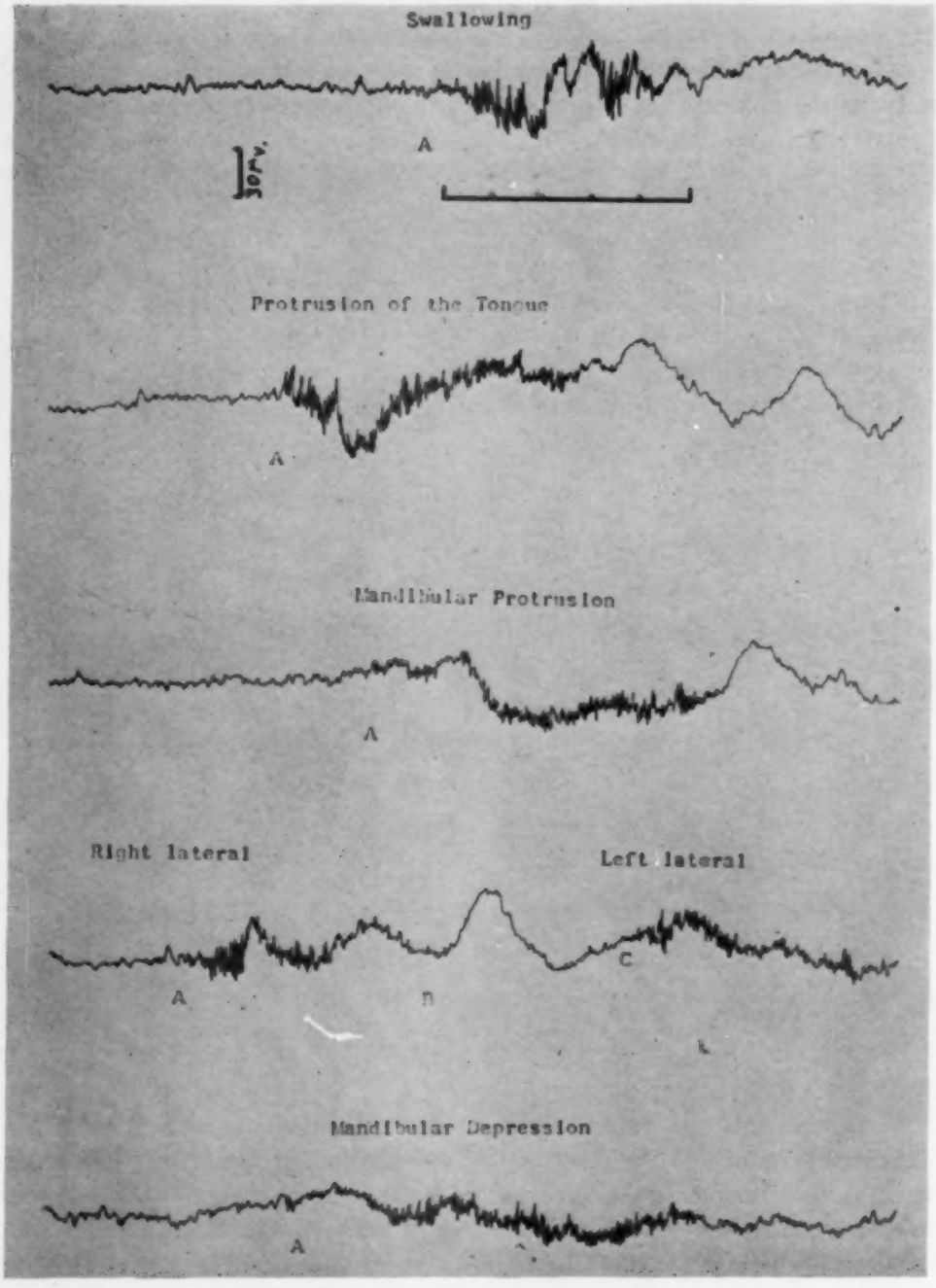

Fig. 21.—The digastric muscle during various movements.

These records were taken consecutively on the same subject. Surface electrodes were used. Note the similarity of the record from this muscle during many different kinds of movement. Time is shown as one-fifth second intervals. *A* indicates the start of movement. *B* is the return to the rest position. *C*, the start of movement in the opposite direction.

movements was sought. The location of the digastric muscle suggests that it might be the suprahyoid muscle most frequently concerned in mandibular depression.

During mandibular depression spike potentials are elicited in the anterior belly of the digastric muscle (Fig. 4). While there is some tensing of the muscle almost at once, the contractions do not reach their maximum amplitude until sometime after those of the external pterygoid. A similar electromyographic record is obtained from this muscle when the tongue is protruded or a fricative or tongue tip consonant is formed. Much the same kind of picture is also seen during swallowing. In fact, the digastric demonstrates spiking during all mandibular movements. Fig. 21 gives a comparison of several records from the anterior belly of the digastric muscle illustrating the participation of this muscle in many different kinds of movements. It can be noted in these records that the amplitude is not greater for depression than for protrusion of the tongue or lateral mandibular movements of the mandible. This type of record strongly suggests an important action of maintaining the position of the hyoid bone and stabilizing the movements of the mandible in such a way as to give smoothness to any action of the lower jaw. Surface electrodes over the sternohyoid muscle indicate that it may have a similar role of stabilizing the hyoid bone during mandibular movements. It is true that the digastric does not instigate mandibular depression, yet it plays an important part in bringing this movement to a synchronous completion. One patient was examined, through the courtesy of the State University of Iowa Hospitals, in which the digastric muscles had been extirpated. The mandible could be depressed but the movement was jerky and irregular, particularly in the latter stages of the movement. It is reasonable to believe, then, that the role of the digastric during most mandibular movements is to stabilize and govern the action, not to initiate it; to regulate, not to instigate.

DISCUSSION

Muscles Involved in Mandibular Depression.—There has been a controversy in the literature for many years as to what muscle is the principal depressor of the lower jaw. Many have insisted that the suprahyoids carry out this action (Riesner[61] and Friel[28]). This view is supported by most of the standard anatomy textbooks as well. Certain others have declared as strongly that the external pterygoid is the sole depressor of the mandible (Root,[65] Wilson,[81] Lord,[49, 50] and Seward[67]). The findings of this study indicate that both muscles take part in this action. Furthermore, electromyographic findings often challenge the use of such phrases as "the prime mover" of a joint. It is true that the external pterygoid demonstrates strong contractions prior to those appearing in the suprahyoids and that they have a greater amplitude; but it is also true that the movement cannot be carried to its final normal completion without the contraction of the anterior belly of the digastric muscle.

Cases have been reported in which bilateral condylectomy was performed due to ankylosis of the temporomandibular articulation (Root[65]). In such individuals the jaw can still be opened by the suprahyoids, but it cannot be opened as far nor is the movement so synchronous. The hypertrophy of these muscles

under such conditions indicates that they are taking on a function to an extent not ordinarily theirs. In cases reported in which the suprahyoids have been removed (Root[65]), the mandibular opening takes place in a near normal manner. An interesting aspect of the study of the suprahyoids is the fact that spike potentials of equal amplitude to those of the digastric were observed by the writer to be elicited from the sternohyoid during mandibular depression. Both the suprahyoids and infrahyoids may have a function of maintaining the position of the hyoid bone during mandibular movements, speech, and swallowing. Lord[49, 50] said that the suprahyoids take part in depression of the mandible only on forced opening. There is an increase in the strength of the contraction from the digastric during forced opening, and its contractions begin sooner, but it always takes part in the movement. It can be concluded that the external pterygoid is more responsible for the initiation of mandibular depression but that the digastric plays an important role in completing the movement.

Synergia at the Temporomandibular Articulation.—While it is customary for the actions of the individual muscle to be discussed separately in anatomy textbooks, this often causes one to lose sight of the synergistic action which takes place around any joint. Electromyographic records taken from several muscles simultaneously clearly point up the close interaction of muscles in completing a given action. It is also customary procedure to designate one muscle as the prime mover of a bone during a certain action or to name another as the principal elevator, flexor, or extensor. Thus, many references are seen in the literature in which the action of the muscles around an articulation is described in a few sentences ascribing muscle *A* to the function of flexion, muscle *B* to extension, etc. Previous electromyographic studies on other articulations (Inman, Saunders, and Abbott[43] and Dempster and Finerty[18]) emphasized the cooperation of several muscles in bringing about any specific movement.

It may be true that one muscle demonstrates greater strength of contractions during a given movement and thus can be said to be contributing the most work toward the final results. Such a muscle might also be said to be the "prime mover" of the joint in that particular action, but care must be taken to avoid arbitrarily assuming that this also means that this muscle has the most important function in bringing about the final action. No movement of the temporomandibular articulation was observed in which contractions were demonstrated in one muscle alone. This fact makes it difficult always to term one particular muscle the principal mover of the joint in a given action. For example, in protraction of the mandible, action potentials are elicited in the external pterygoid muscles, the internal pterygoid muscles, and the suprahyoid group. Which muscle can be said to be primarily responsible for this action? Could any single muscle carry out such a complicated action alone? It is easy to designate the role of the suprahyoids as being of a secondary nature in this case, but it is more difficult to deny that they have an important function in stabilizing the jaw during the movement. At other times muscles may be ascribed a passive role in a movement, e.g., the right pterygoid muscles during abduction of the menton toward the right side of the body. Passive participa-

tion in a movement then is that in which the muscles are not instrumental in bringing about the action, yet the contraction patterns seen are not those of a resting muscle.

The harmonious cooperation and interaction of the muscles around the temporomandibular articulation are observed in every mandibular movement. It becomes difficult in view of this fact to describe the movements of the joint in terms of contracting single muscles. The picture is one of movement brought about by accurate, delicate muscle contractions harmoniously carried out under the coordinating direction of the central nervous system.

The Mandible as a Third-Class Lever.—It has been almost traditional to describe the mandible as a lever of the third-class (the power between the fulcrum and the resistance). This concept has been handed down from textbook to textbook and repeated again and again. Sicher[70] and Robinson[64] showed that the type of tissue in the joint is not that regularly associated with stress-bearing joints. Wilson[81] pointed out that the blood vessels ordinarily enter a bone in the area of least movement which might indicate that the fulcrum was in the ramus. It is difficult to visualize the mandible as a third order lever in view of the findings of this study. It is much easier to interpret the electromyograms in the light of Robinson's[64] theory of a nonlever action of the mandible. The direction of the muscle pull, the sequence of the contractions, and the action of synergists all show that the resultant force is in the denture. There can be no lever action when the resistance is directly in line with the resultant of the applied power; such is the case in the mandible. The teeth and their supporting structures thus bear the heavy stresses for which they are designed and the joint is normally free of heavy strain.

Reflex Control of the Temporomandibular Joint.—For the concept of a nonlever controlled joint, as advanced by Robinson,[64] to hold, some mechanism must be shown to exist which will protect the joint from strain and still carry the mandible through the various movements necessary for masticatory efficiency. Corbin[14] and Corbin and Harrison[15] provided a clue to the answer in their description of the course of the proprioceptive fibers from the temporomandibular mechanism and the periodontal membrane. Fibers of the mesencephalic root of the fifth cranial nerve are found in both the muscles of mastication and the periodontal membranes of the teeth of the maxilla and the mandible. Afferent proprioceptive impulses relaying unconscious senstations of position of the mandible and pressure of food thus have a pathway to the brain. A reflex arc is thus established with the motor root of the fifth nerve which can synchronize the muscles of mastication. Robinson[64] stated: "The normal rest position of the mandible must be thought of as an active process. A constant shower of impulses come to the brain from the tension in the muscles, largely from overcoming the force of gravity. These afferent impulses reflexly control the motor fifth nucleus to maintain the jaw in the 'rest' position. By this method we keep the mandible in position against gravity in the same way that we control other antigravity muscles." Sherrington,[69] who studied this reflex arc in the cat, said: "On the mouth's seizing a morsel, the mandible, when it has closed, e.g., volun-

tarily, upon whatever is between the jaws, pressing it against the teeth, by so doing, as is clear from observations of the reflex, produces a stimulus which tends reflexly to reopen the jaws. That done, the central rebound of the previously inhibited motor neurones sets in and tends to powerfully reclose the jaws again. The reclosure brings into operation once again the jaw-opening stimulus. And so, after being started by a first bite, a rhythmic masticatory reflex tends to keep itself going so long as there is something biteable between the teeth."

This reflex control of the mandible places significance upon the role of antagonists and synergists during any action. Any muscle contracting alone and without the reflexly controlled attenuating action of antagonists and synergists could not carry out the many delicate actions of the temporomandibular articulation. Furthermore, the teeth and supporting structures could not withstand the trauma of mastication without this protective mechanism. While one muscle may be described as the prime mover of the mandible during a certain action, the contractions appearing in other muscles are most important. They aid in the coordination, synchronization, and attenuation of the action of the initially contracting muscle so that the final result is a smooth, delicately regulated movement.

The cerebellum is largely responsible for synergia. "When the cerebellum is removed, delicately adjusted movements are forever made impossible" (Fulton[29]). Proprioceptive and inhibitory mechanisms are interacted in such a manner that "the end-effect of the two varieties of influence is a more gradual and more delicately adjusted movement of the muscle under excitatory stimulation" (Fulton[29]). It is entirely probable that the cerebellum participates in the coordination of the finely adjusted contraction of the muscles which confer movement on the mandible. There are undoubtedly other central nervous mechanisms interacting between the conscious and unconscious regulation of muscular contraction patterns.

Mackenzie[51] stated, ". . . when the whole muscle acts it produces one general effect, having one defined action." This might be true for the simple contraction of certain individual muscles. The results of this study show that such is seldom the case, however, in the temporomandibular articulation. The pure contraction of a single muscle does not occur. Instead, several muscles are acting together in a harmonious cooperation. One muscle may be exhibiting greater strength of contractions and thus designated as the mover of the joint, but other muscles are also involved in the movement. Furthermore, these contractions of the synergists are not necessarily having the same effect as when these muscles are contracting maximally. There is a blending of the effects of these contractions to such an extent that the purity of action of Mackenzie is not seen. Instead, the resultant of the contractions is a product not possible of attainment by the single contraction of any given muscle. Beevor[6] understood this concept when he wrote, "The brain knows nothing of the action of individual muscles, but only of movement. . . . There is a central pattern of motion carried to the

periphery.'' Although this undoubtedly oversimplifies the problem, the picture still is one of motion produced by the coordinated stimulation and action of individual muscles.

Splinting.—When needle electrodes are in place in certain muscles the readings in other muscles may be affected by ''splinting'' action. Magoun and Rhines[52] described this phenomenon as a mechanism for protecting the joint against damage: ''The physiologist has long known that superficial pain is capable of eliciting motor activity and in the extremities of the laboratory animal this occurs as the classical flexor contraction of the painfully stimulated member with extension of the crossed limb. It has logically been pointed out that this act is purposeful, its objective being to withdraw the stimulated part from a potentially injurious aspect of the environment and, at the same time,

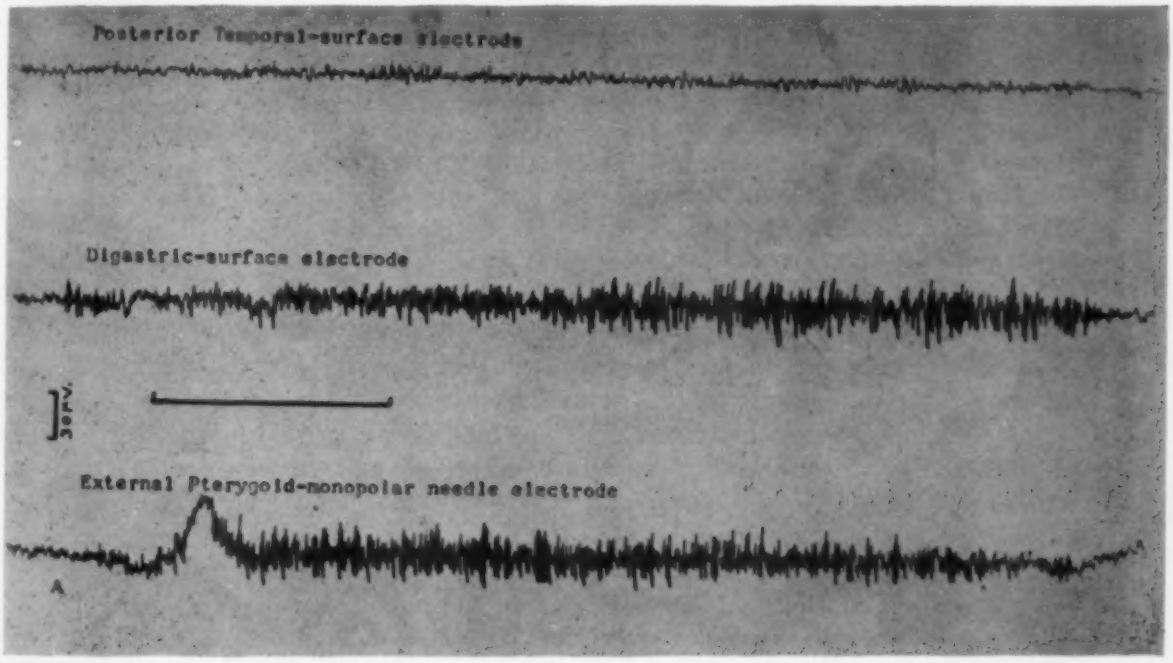

Fig. 22.—Splinting in the digastric muscle. Time is shown as one second. Compare this record with Fig. 4 where, though the recording was done in a similar fashion, no splinting is seen.

augment the supporting strength of the opposite leg which must by itself bear the animal's weight during this action. It may be that deep pain arising, for example, within a stretched muscle evokes some modification of the classical flexor reflex, designed not to pull the member away from the source of pain, which in this case is impossible since the source is inside it, but to maintain a balance of tension in the stretched and adjacent muscles which reduces pain to a minimum. If this were the case, deep pain might, under some conditions, constitute a stimulus of importance equivalent to stretch in maintaining muscle tension and one hitherto inadequately emphasized in neurophysiology.''

An example of the ''splinting'' action is seen when a needle electrode is used in taking readings from an external pterygoid muscle. In this case signifi-

cant increases in both amplitude and frequency sometimes are seen in the anterior belly of the digastric muscle. The records thus obtained would seem to indicate that the digastric was demonstrating earlier and stronger contractions than is really the case. Further, under these conditions, contractions may be seen in muscles which are not ordinarily involved in the action. When the needle is withdrawn and the afferent pain impulses have subsided, the normal picture is once more seen. In this manner it can be deducted that the early contractions demonstrated in the digastric when needle electrodes are in place in either the internal or external pterygoids are actually a result of "splinting." An example of splinting is seen in the digastric muscle in Fig. 22. Little, however, is seen in Fig. 4, although both records were obtained with needle electrodes present in other muscles while the digastric records were being taken.

Changes in Closure Pattern With Age.—Certain alterations in closure pattern occur with age as the result of an experience peculiar to the individual affected. No changes were observed which were common to all subjects. During the peroid of transition from the primary to the permanent dentition the position of certain deciduous teeth is often altered by the pressure of erupting permanent teeth. When these primary teeth are moved from the line of occlusion they interfere with the interdigitation until they are exfoliated. This necessitates a new closure path to avoid hitting the malplaced tooth and to allow complete interdigitation of the cusps.

Reflexly, a new closure pattern is acquired so that the malpositioned tooth is automatically avoided. The chin point describes, on elevation of the mandible, a tortuous S-curved path, whereas ordinarily it adheres to the midline of the body. The new closure path is brought about by compensating contractions of the elevators which cause lateral shifting that allows malpositioned teeth to be missed (Figs. 16, 17, and 18). Ordinarily the changes in sequence of contraction are but a transitory affair until the tooth is lost. However, if the tooth is retained in its unusual position for some time, a new permanent closure pattern and path may be acquired. It was noted in this study that these alterations of function are most frequently seen in the internal pterygoid and temporal muscles. In cases of marked malocclusion they are a more frequent finding (Moyers[56]). The subjects on whom these findings are based are listed in Table III with pertinent data on the teeth involved.

SUMMARY AND CONCLUSIONS

An electromyographic analysis of certain muscles involved in movement at the temporomandibular articulation is presented. The data were collected on an electroencephalograph with crystographic inkwriting recorder. The subjects were normal children and adults free from temporomandibular articulatory difficulties. The experiments demonstrated the following:

1. The various movements of the temporomandibular articulation are affected by the regulated interaction of several muscles.

2. Mandibular depression is brought about by contractions of both the external pterygoid and digastric muscles, though the latter participates in the action to a greater extent at the end than at the beginning of the movement.

3. Elevation of the mandible is achieved by the coordinated contractions of the internal pterygoid, masseter, and temporal muscles.

4. Lateral movements of the mandible are brought about by the ipsilateral contraction of the temporal muscle and the contralateral contractions of the external pterygoid and internal pterygoid muscles.

5. Protraction of the mandible is achieved by the simultaneous contractions of both the external and internal pterygoid muscles.

6. Retraction of the mandible is effected by the contraction of the middle and posterior fibers of the temporal muscle.

7. In all movements of the mandible the suprahyoid muscle group has an important role in stabilizing the bone to achieve a more delicately adjusted action.

8. No changes are seen in the function of the various temporomandibular muscles from the time of the deciduous dentition to adulthood, except occasional transitory alterations in the internal pterygoid and temporal muscles. These occur as a reflex attempt to avoid malposed deciduous teeth in the process of exfoliation.

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THE FRANKFORT-MANDIBULAR PLANE ANGLE AND THE FACIAL PATTERN

ERNEST L. JOHNSON, D.D.S., F.A.C.D.,* SAN FRANCISCO, CALIF.

SOME years ago a great industrial leader was asked to explain the amazing advancement of American industries. His reply was short, but factual, for he said: "We progress only when we are capable of using the thoughts of many." How well this applies to the American sciences, and particularly to orthodontics. There can be no doubt that the amazing advancement in the field of orthodontics has been due to the contribution of the thoughts of many. It is hoped that this work will contribute toward that progress.

Since 1946, when Tweed[1] described his method of using the Frankfort-mandibular plane angle (as measured from lateral photographs) in orthodontic diagnosis, classifications, and treatment planning, the use of this particular measurement of facial morphology has rapidly won favor among orthodontists. Downs[2] included this among ten important measurements taken from cephalometric head films, and provided a mean value and maximal and minimal values derived from a group of individuals having excellent occlusion. Salzmann[3] described an instrument for measuring the Frankfort-mandibular plane angle and other angles without the use of roentgenographic equipment. Continued use testifies to the fact that the Frankfort-mandibular angle is clinically useful. It is therefore not disparaging to remark that this angle, like other angles, is a measure of the relative position of the points which by definition form the angle. Angles seldom, if ever, provide any true indication or absolute measure of the specific location of the departure from acceptable facial morphology. Angles will always continue to be useful in the assessment of craniofacial morphology, since it has been demonstrated[4] that these angles remain relatively unchanged from birth to maturity, and that to a large extent age differences may therefore be ignored. At the same time it is highly desirable to know where exactly facial morphology veers away from desirable standards, and in that search we are often obliged to use methods of measurement other than angles.

That there is a change in orthodontic thinking is becoming increasingly more apparent. Brodie[5] and Wylie[6] have both called for reorientation of orthodontic thinking concerning the basis of deviations from the so-called "normal" facial pattern, and have maintained that these aberrations should not necessarily be considered as defects of growth, nor as undesirable postnatal alterations in craniofacial morphology, nor even as abnormalities. Instead it has been suggested by them that many of these facial patterns which orthodontists find undesirable are in reality only the random combination of separate facial parts, each of which is within the normal range of variation in conformation and size, but which in toto combine to produce an undesirable facial configuration.

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*Demonstrator in Orthodontics, University of California.

While it would be unwise to say that orthodontists have accepted all the views stated in the two articles last mentioned, on the other hand there has been at least a tacit acceptance of this philosophy among orthodontists in recent years, as testified by the fact that orthodontists today are more inclined to describe the facial patterns, often quantitatively, rather than explain why they occur. Wylie[7] recently advanced a quantitative method for the assessment of craniofacial dysplasia in the anteroposterior plane of space, using linear values measured in millimeters rather than angles. With this method, it is possible to localize anteroposterior dysplasia in the cranial base, in the length or lack of it in the maxilla or the mandible, and in the placement of the maxillary dental arch upon its bony base. This system of assessment of anteroposterior dysplasia also has some use in ferreting out cases in which abnormal arch relationships are due to mandibular displacement, as described by Thompson.[8]

This study is intended to explain, in specific and localized terms, how and why the facial pattern is bad when the Frankfort-mandibular plane angle becomes increasingly large.

If it is possible to state that some single anatomical factor is responsible for the undesirable facial conformation which is characterized by a steep mandibular plane angle, then systematic measurement of a group of patients properly classified with respect to that angle should demonstrate the fact. Furthermore, if this kind of facial pattern is characterized by two or more anatomical departures from the typical facial morphology, measurement should also demonstrate this and, perhaps, even indicate the interrelationship between the two or more factors involved.

The great variety of differences in human facial pattern made the preliminary organization of these data somewhat difficult. It is relatively easy to find isolated cases which will support a particular theory propounded to explain a specific kind of facial pattern, and further search will even make it possible to duplicate with similar cases instances of the same kind which can reinforce the theory further. On the other hand, when 150 cases are assembled, with no preconceived notion to be substantiated, contradictions and exceptions and extremes in facial pattern crop up to make it very obvious that simple and limited explanations for variations in facial morphology can never suffice. Faces vary from one to another and for many different reasons.

One hundred fifty lateral cephalometric head films from the University of California Orthodontic Clinic were used. These were selected at random to give as good as possible a cross section of the orthodontic material presenting to the clinic. Care was taken to select only patients with full components of teeth, as mutilated cases would be misleading. Also, care was taken to be sure there was a fair sample of cases with good occlusion and acceptable facial morphology to act as a control.

Tracings of these head films were made and the following measurements in millimeters taken as illustrated in Fig. 1:

A. The total face height as measured from nasion to gnathion.

B. The upper face height as measured on the line nasion-gnathion from the projection of the anterior nasal spine to nasion.

C. The lower face height as measured on the line nasion-gnathion from the projection of the anterior nasal spine to gnathion.

D. The perpendicular measurement from the incisal edge of the upper central incisor to the Frankfort plane.

E. The perpendicular measurement from the incisal edge of the upper central incisor to the maxillary base line. This base line is established by passing a line through the posterior and anterior nasal spines.

F. The angle formed by the interection of the mandibular plane with the long axis of the lower central incisor. The number of degrees over ninety is registered as positive and the number of degrees less than ninety as negative.

G. The perpendicular measurements from the incisal edge of the lower central insisor to the mandibular plane.

H. The perpendicular measurement from the occlusal plane (in the center of the first molar) to the mandibular plane.

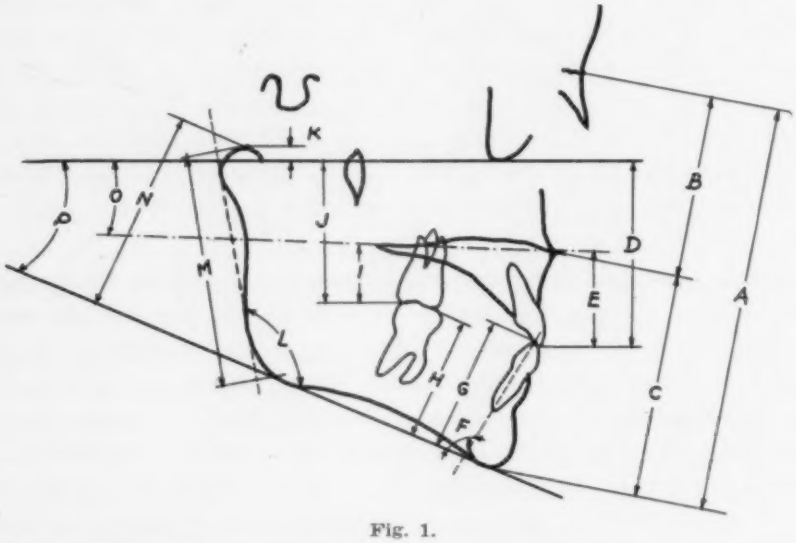


Fig. 1.

A, The total face height, nasion to gnathion.

B, The upper face height, nasion to anterior nasal spine.

C, The lower face height, anterior nasal spine to gnathion.

D, Incisal edge of the upper central incisors to the Frankfort plane.

E, Incisal edge of the upper central incisors to the maxillary base.

F, The lower incisor-mandibular plane angle. The number of degrees over ninety is registered as positive and the number of degrees less than ninety as negative.

G, Incisal edge of the lower central incisor to the mandibular plane.

H, Occlusal plane (in the center of the first molar) to the mandibular plane.

I, The occlusal plane (first molar region) to the maxillary base.

J, The occlusal plane (first molar region) to the Frankfort plane.

K, The summit of the condyle to the Frankfort plane. If the summit of the condyle is above the Frankfort plane, the measurement is positive; if below, the measurement is negative.

L, The gonial angle (formed by the tangent to the posterior border of the ramus and the mandibular plane).

M, The summit of the condyle to gonion.

N, The summit of the condyle to the mandibular plane.

O, The Frankfort-maxillary base angle.

P, The Frankfort-mandibular plane angle.

I. The perpendicular measurement from the occlusal plane (in the center of the first molar region) to the maxillary base line.

J. The perpendicular measurement from the occlusal plane (in the center of the first molar region) to the Frankfort plane.

K. The perpendicular measurement from the summit of the condyle to the Frankfort plane. The point used is the mean between the two condyles. If the summit of the condyle is above the Frankfort plane, the measurement is positive, if below, the measurement is negative.

L. The gonial angle formed by the tangent to the posterior border of the ramus and the mandibular plane.

M. The length of the ramus from the summit of the condyle to gonion.

N. The perpendicular measurement from the summit of the condyle to the mandibular plane.

O. The angle formed by the Frankfort plane and the maxillary base line (Frankfort-maxillary base angle). This angle is positive if the planes converge posteriorly.

P. The angle formed by the Frankfort plane and the mandibular plane (Frankfort-mandibular plane angle).

In order to evaluate the material, it was divided into four groups, determined by the Frankfort-mandibular plane angle (Table I). There were 47 cases with the Frankfort-mandibular plane angle 25° or less, 49 with the Frankfort-mandibular plane angle between 26° and 31° inclusive, 26 with the Frankfort-mandibular plane angle between 32° and 34° inclusive, and 28 with the Frankfort-mandibular plane angle 35° or more.

A. In looking at the first appraisal "A" of Table I, it will be noted that there is a consistent increase in the total face height (13.28 mm.) as the Frankfort-mandibular plane angle increases.

B. The slight increase of the upper face height (1.65 mm.) as the Frankfort-mandibular plane angle increases shows the tendency of vertical facial growth to predominate over forward growth in the upper face, thus contributing to the increase in total face height.

C. The very marked and consistent increase in the lower face height (11.63 mm.), as the Frankfort-mandibular plane angle increases, is determined mainly by the vertical growth of the mandibular and maxillary alveolar processes, thus making the lower face an important contributor to the total face height, and in turn making it play a major role in determining the Frankfort-mandibular plane angle.

D. This appraisal of the distance between the Frankfort-mandibular plane and the upper central incisors also shows a consistent and rapid increase, as might be expected, for it includes part of the upper face and all of the vertical growth of the upper alveolar process.

E. As with D, there is a consistent increase of the distance between the incisal edge of the upper central incisors and the maxillary base. This is largely the result of the increase in vertical growth of the upper alveolar process, as the Frankfort-mandibular plane angle increases.

F. This shows the importance of considering more than the lower incisor mandibular plane relationship when determining the normal location for this tooth. As the Frankfort-mandibular plane angle increases, the lower incisors become more upright. This is a good thing, or they would be lying forward in the face when the Frankfort-mandibular plane angle is very large. It is probably the muscle pressure of the lower lip that keeps the lower incisors back, even when the bony pattern of the lower jaw would have a predisposing tendency of throwing them forward. Conversely, when the Frankfort-mandibular plane angle is small the lower incisors become more procumbent. In the first group of 47 cases with the Frankfort-mandibular plane angle 25° or less, there were 21 cases with the lower incisor mandibular angle between plus 10 and plus 25°. In the fourth group of 28 cases with the Frankfort-mandibular plane angle 35° or more, there were 6 cases with the lower incisor mandibular angle between minus 5 and minus 14°.

TABLE I

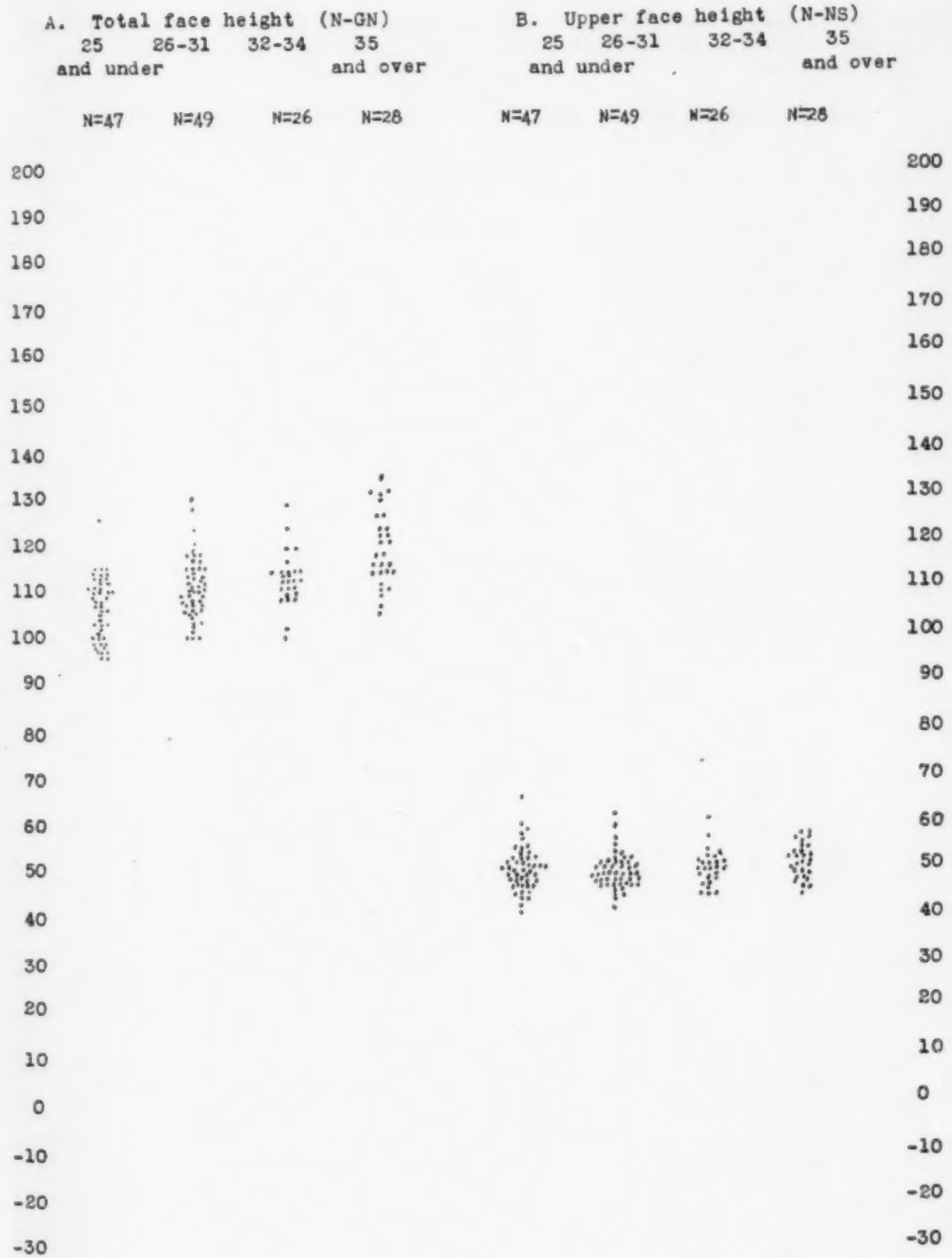
	FRANKFORT-MANDIBULAR PLANE ANGLE			
	25° OR LESS N = 47	26-31° N = 49	32-34° N = 26	35° OR MORE N = 28
A. Total face height nasion-gonion	106.32	109.42	112.46	119.60
B. Upper face height nasion-maxillary base	50.45	48.89	50.00	52.10
C. Lower face height maxillary base-gnathion	55.87	60.53	62.46	67.50
D. Incisal edge upper central to Frankfort plane	50.02	51.55	54.23	55.53
E. Incisal edge upper central to maxillary base	27.34	28.69	29.42	29.64
F. Lower incisor mandibular plane angle	+7.70	+5.77	+3.61	+0.92
G. Incisal edge lower central to mandibular base	40.13	42.55	43.42	44.60
H. Occlusal plane to mandibular plane (first molar region)	31.00	31.24	31.46	32.04
I. Occlusal plane to maxillary base (first molar region)	20.94	21.55	22.04	22.57
J. Occlusal plane to Frankfort plane (first molar region)	43.28	43.26	43.42	45.00
K. Condyle summit to Frankfort plane	+0.02	+1.75	+2.77	+5.17
L. Gonial angle	122.04	126.63	128.81	132.46
M. Condyle summit to gonion	59.98	55.18	54.38	55.64
N. Condyle summit to mandibular plane	52.83	48.51	45.38	44.25
O. Frankfort-maxillary base angle	+0.96	+3.00	+4.69	+6.17
P. Frankfort-mandibular plane angle	21.97	28.34	33.23	38.71

G. The decisive and steady increase (4.47 mm.) in the distance between the incisal edge of the lower central incisors and the mandibular plane illustrates the large part the lower alveolar process contributes to the total face height as the Frankfort-mandibular plane angle increases.

H. The very slight increase (1.04 mm.) in the distance between the occlusal plane and the mandibular plane in the first molar region shows that most of the increase in vertical height is limited to the profile as the Frankfort-mandibular plane angle increases.

I. Although progression exists in the distance between the occlusal plane in the first molar region and the maxillary base, it is very slight (1.63 mm.) in comparison to the increase in the total face height.

J. Similar to I, there is a slight progression (1.72 mm.) in the distance between the occlusal plane in the first molar region and the Frankfort plane as the Frankfort-mandibular plane angle increases.


A. Total face height (N-GN)
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
B. Upper face height (N-NS)
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
200
190
180
170
160
150
140
130
120
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-10
-20
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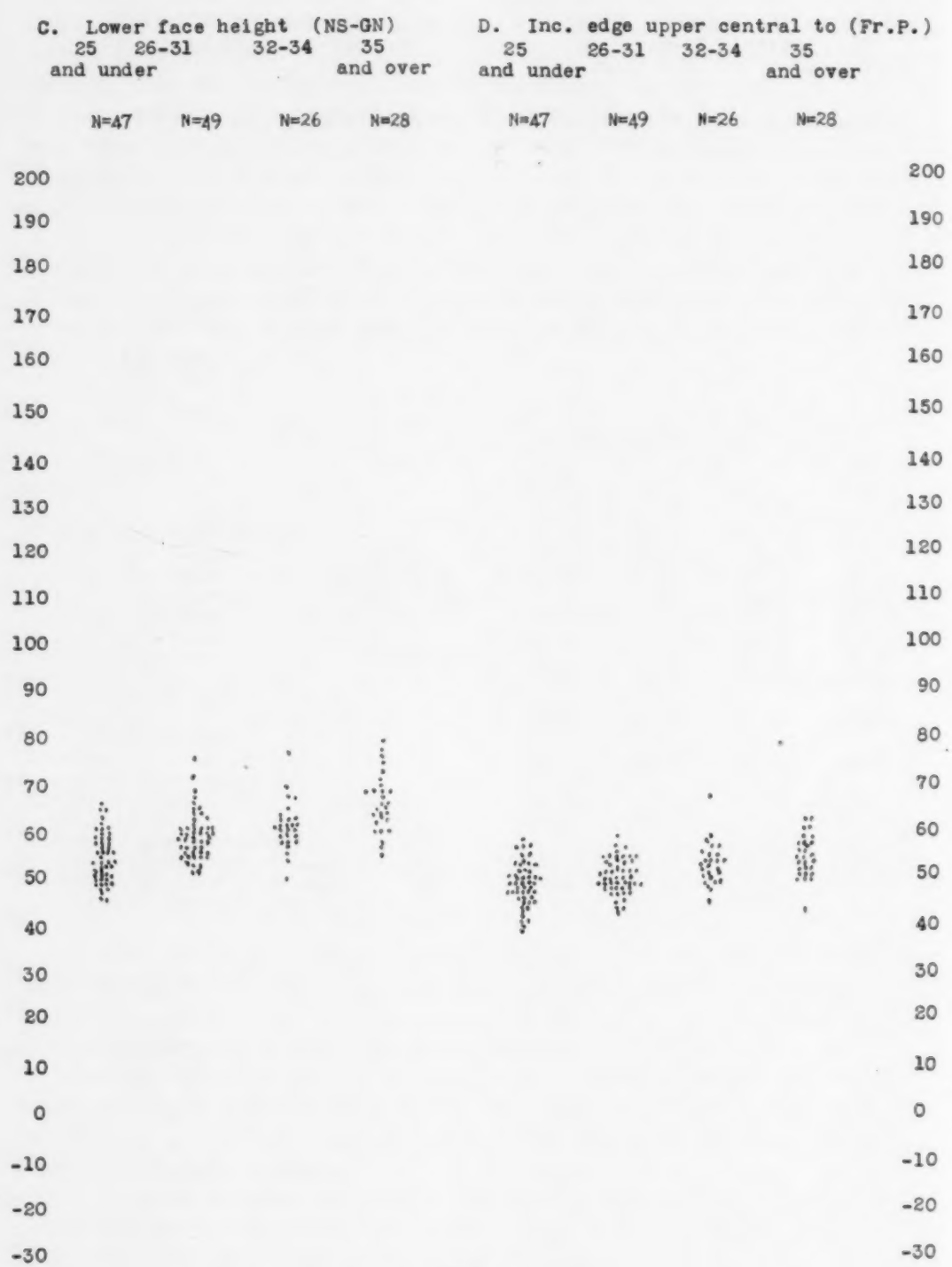
Fig. 2.


C. Lower face height (NS-GN)
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
D. Inc. edge upper central to (Fr.P.)
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
200
190
180
170
160
150
140
130
120
110
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90
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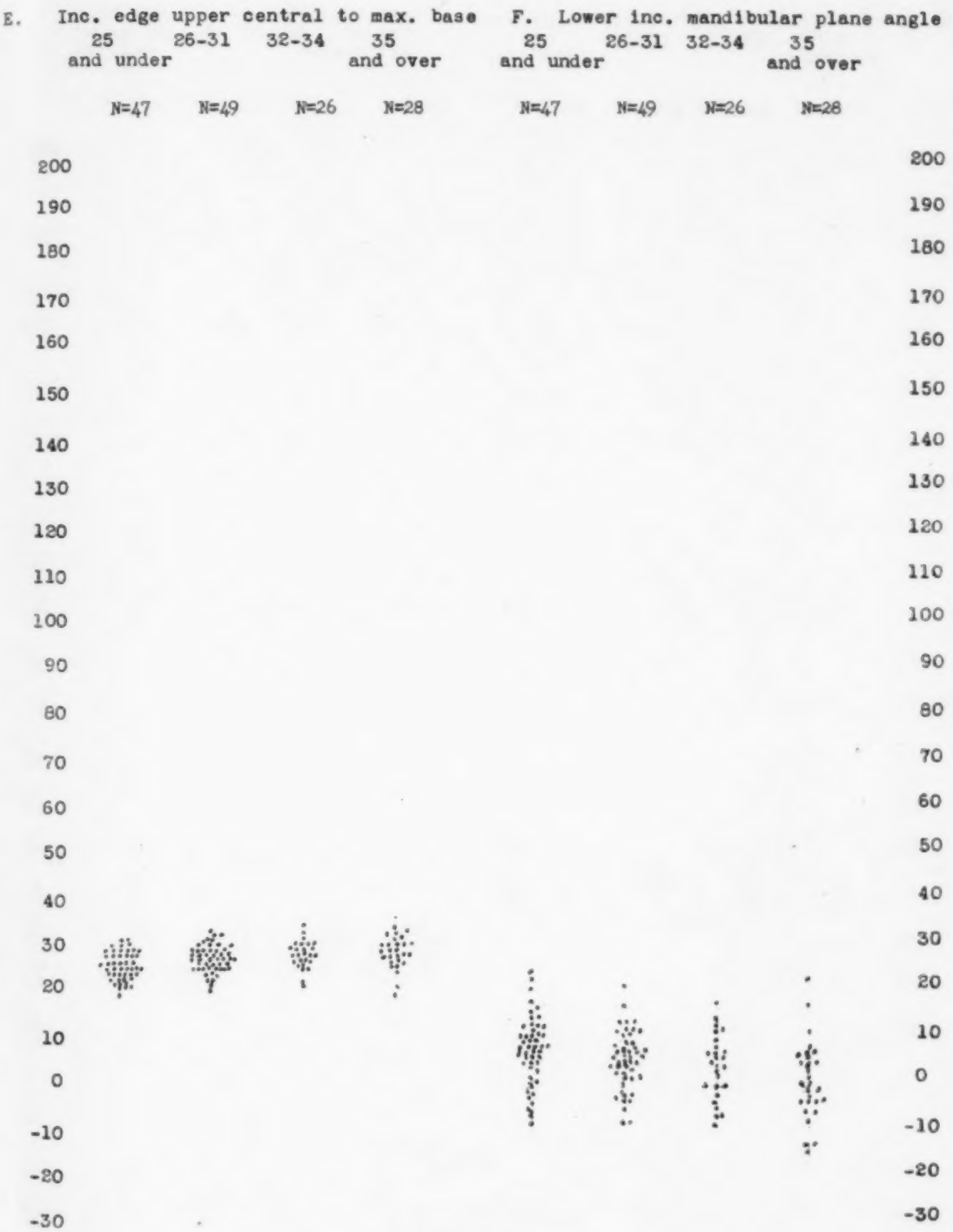
-10
-20
-30

Fig. 3.


E. Inc. edge upper central to max. base
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
F. Lower inc. mandibular plane angle
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
200
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180
170
160
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-10
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Fig. 4.

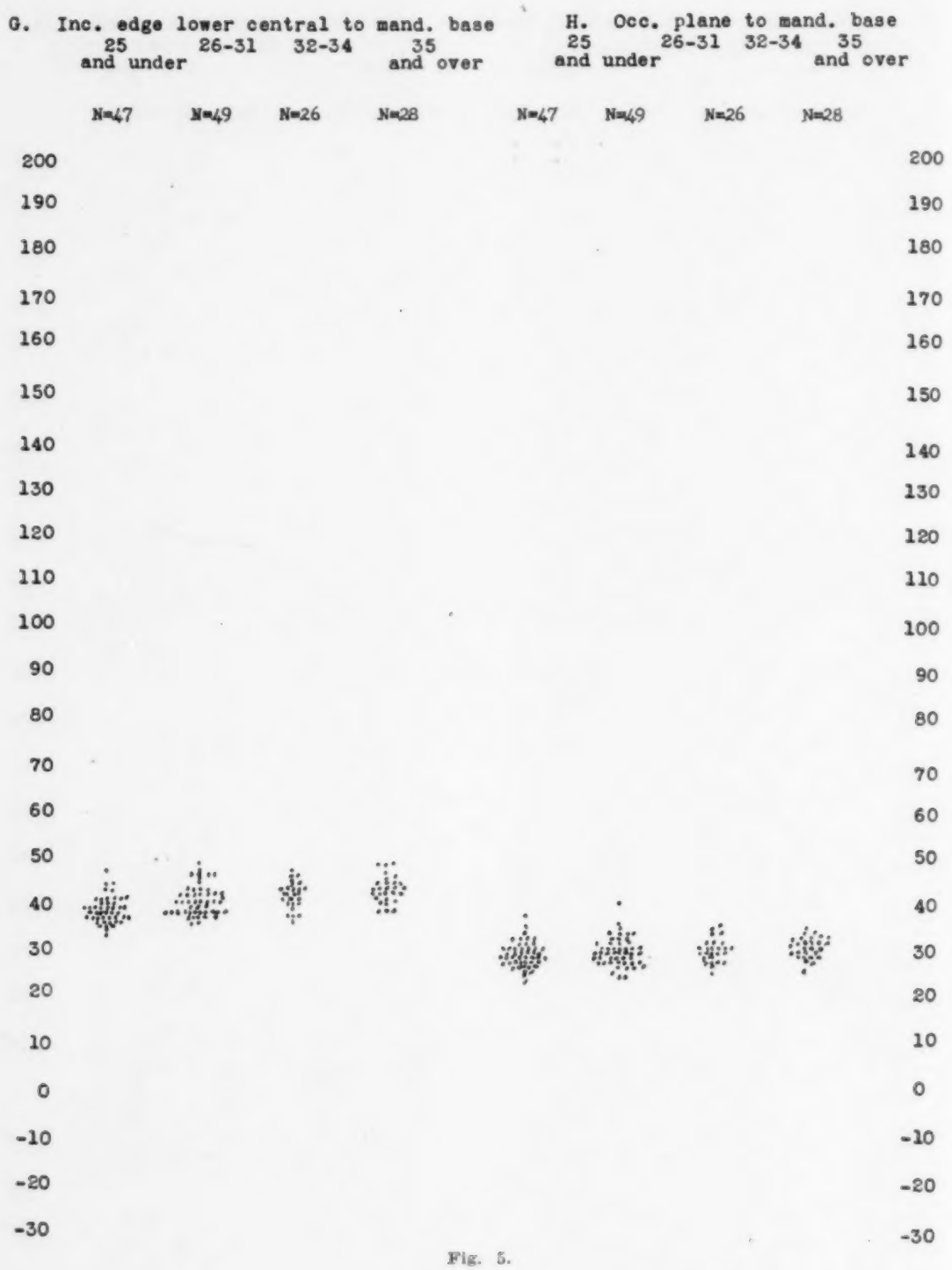
G. Inc. edge lower central to mand. base
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
H. Occ. plane to mand. base
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
200
190
180
170
160
150
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Fig. 5.

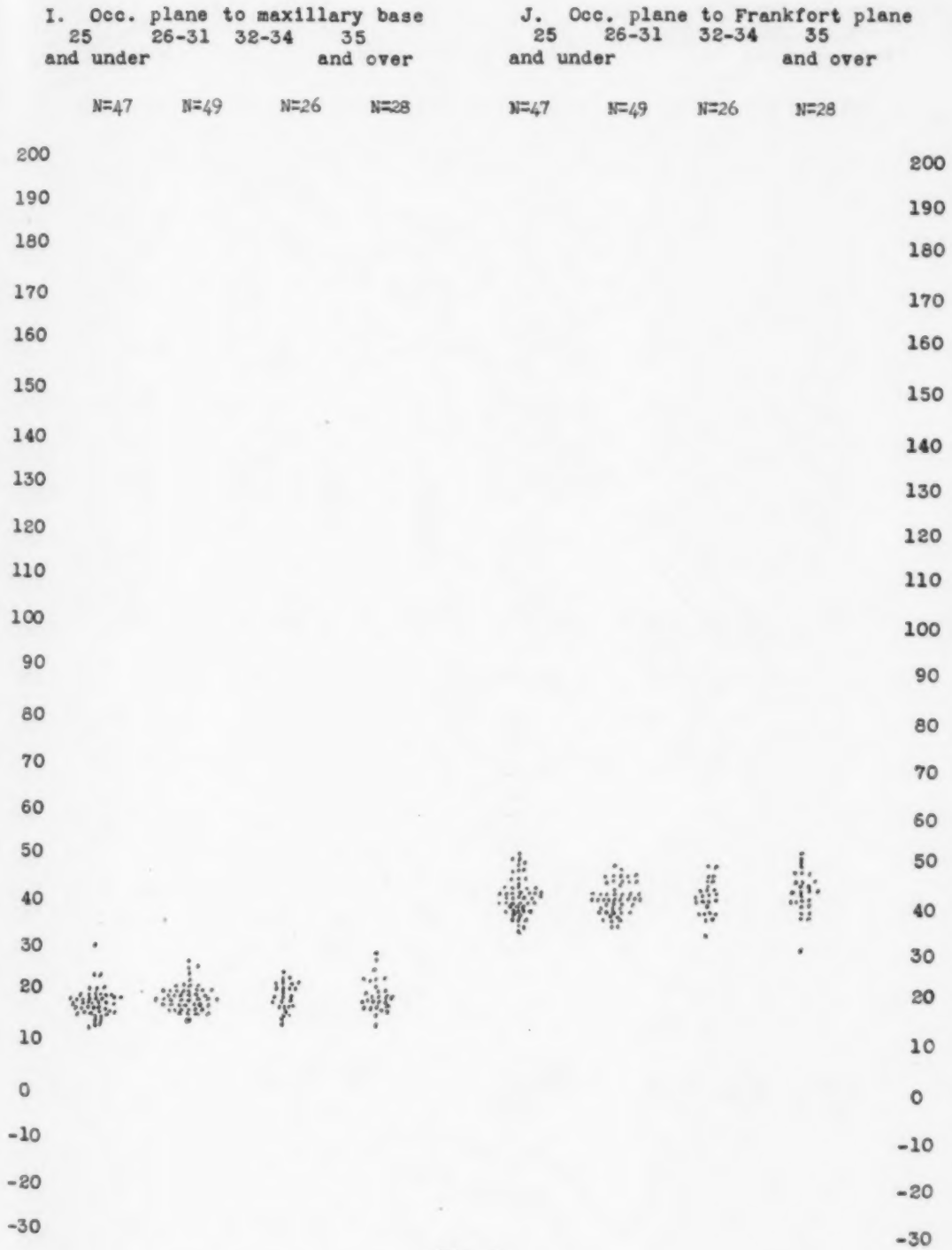
I. Occ. plane to maxillary base
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
J. Occ. plane to Frankfort plane
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
200
190
180
170
160
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Fig. 6.

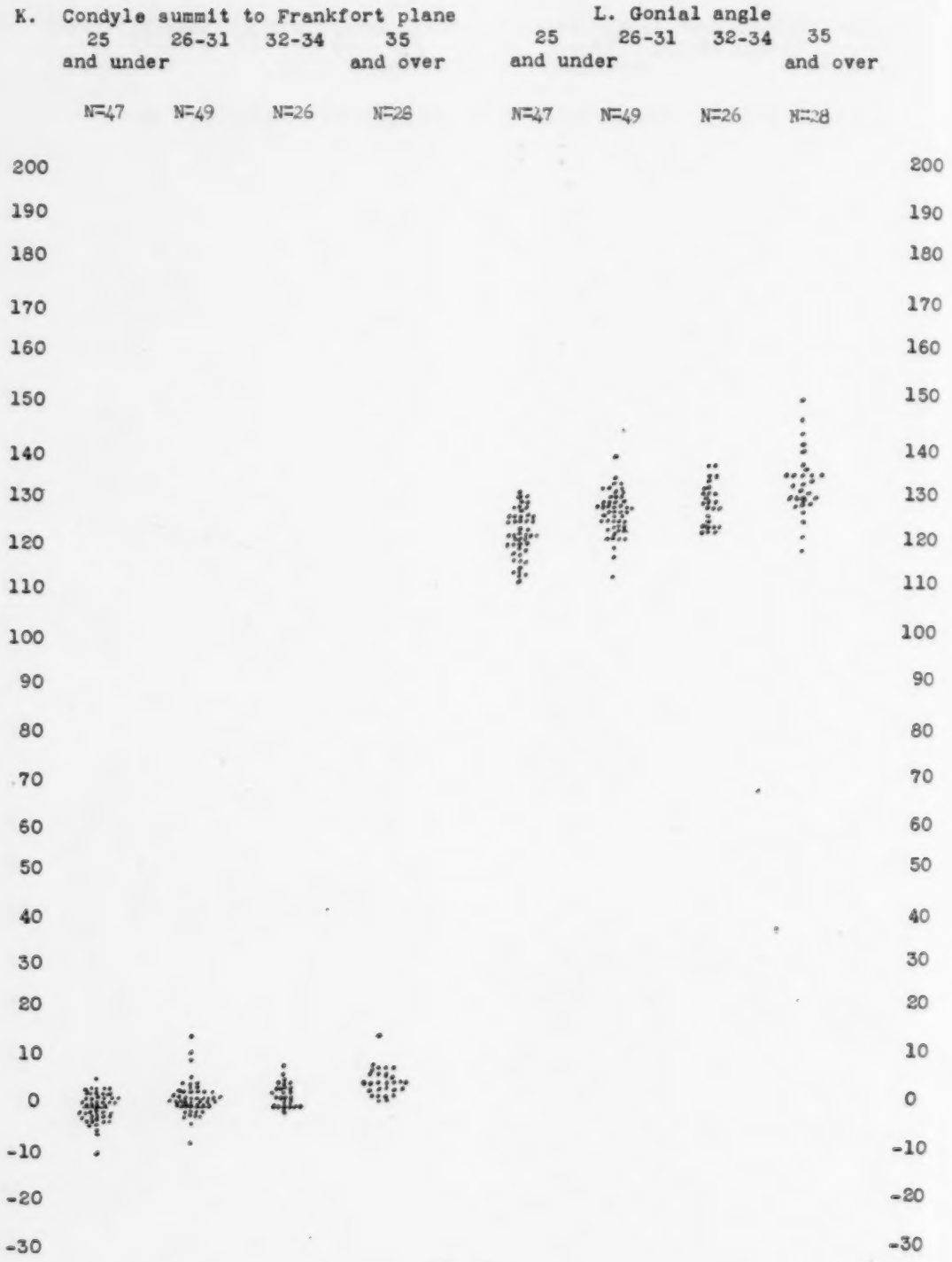
K. Condyle summit to Frankfort plane
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
L. Gonial angle
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
200
190
180
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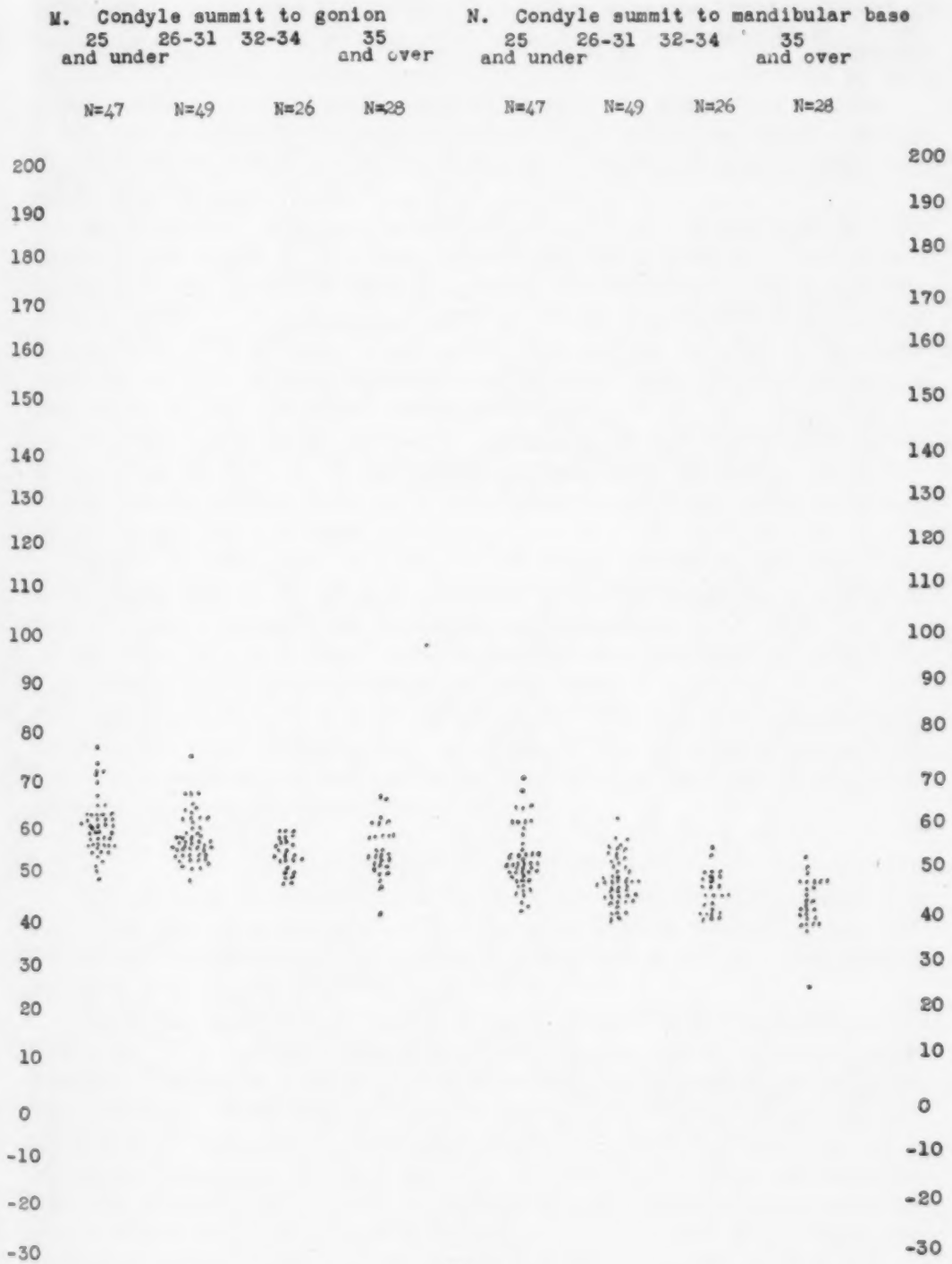
Fig. 7.


M. Condyle summit to gonion
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
N. Condyle summit to mandibular base
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
200
190
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160
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Fig. 8.

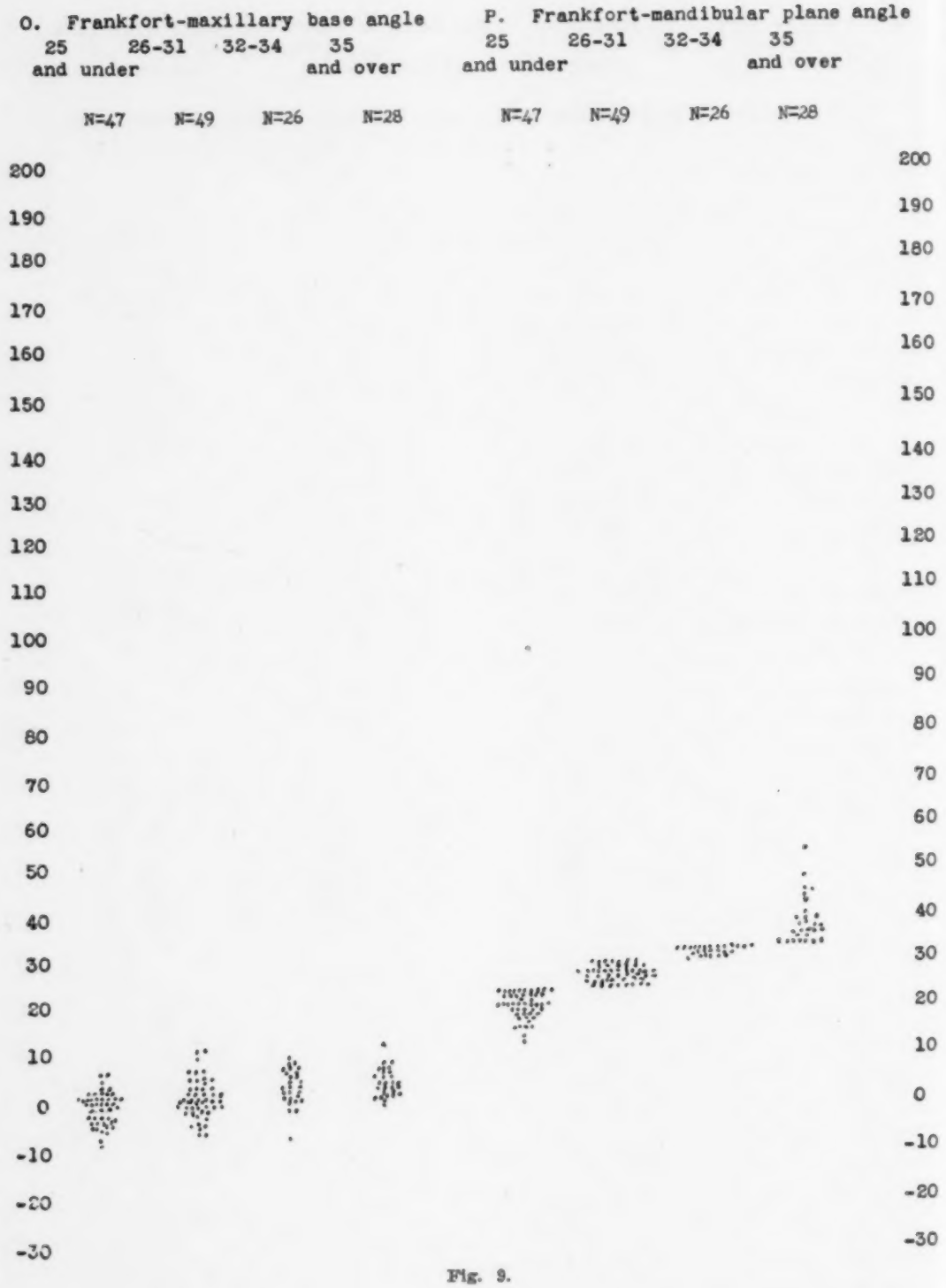
O. Frankfort-maxillary base angle
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
P. Frankfort-mandibular plane angle
25 and under
26-31
32-34
35 and over
N=47
N=49
N=26
N=28
200
190
180
170
160
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Fig. 9.

K. As the head of the condyle is progressively placed further above the Frankfort plane, tending to exaggerate the lack of sufficient vertical height in the ramus, the Frankfort-mandibular plane angle increases. The rapid increase from plus 0.02 to plus 5.17 shows that the location of the head of the condyle in the skull plays a very important part in determining the entire facial pattern, as well as the Frankfort-mandibular plane angle.

L. There is steady and rapid increase in the size of the gonial angle, as the Frankfort-mandibular plane angle increases, which goes hand in hand with the increase in facial height.

M. Where the Frankfort-mandibular plane angle is less than 25°, the mean vertical length of the ramus (condyle summit to gonion) is substantially larger than the means for the other groups; the three remaining groups have mean values for this measurement which are within a millimeter of one another. It was expected that ramus length would have a larger influence on the determination of the Frankfort-mandibular plane angle than is indicated here, and this will be discussed in a later portion of the paper.

N. The distance from the condyle summit to the mandibular plane diminishes as the mean Frankfort-mandibular plane angle increases. We should expect this for this measurement is the effective length of the ramus, as altered by the increasing gonial angle.

O. The definite and consistent increase in the Frankfort-mandibular base angle shows that as the vertical height of the profile increases, it affects the cant of the palate by carrying the anterior end downward.

P. This shows the mean Frankfort-mandibular plane angle in each of the four divisions of the group of one hundred fifty cases.

Figs. 2, 3, 4, 5, 6, 7, 8, and 9 are graphs showing each of the measurements of the individuals comprising the four groups. They show the wide variation, even within each group, and yet the definite trend as expressed in the means for each of the four groups as shown in Table I.

CLINICAL IMPLICATIONS

It appears to me that much of the value of similar studies is often lost to the reader because so frequently the investigator neglects to explain adequately the clinical implications of his study. Hence, I will attempt to present a summary of my thoughts on this survey.

Facial patterns are of utmost importance in orthodontic prognosis and treatment. There would appear to be little doubt that facial patterns are determined by heredity, in large part, or by other deep-seated factors not susceptible to modification. There may be a great deviation in the individual pattern from the so-called "normal" or ideal type or pattern. Yet, these extremes are in one sense normal for that individual, and many of the individual deviations from the acceptable pattern are not within the realm of orthodontic correction.

As was pointed out earlier in this paper, the magnitude of the Frankfort-mandibular plane angle must be regarded as the result of relatively greater development in certain areas of the face than others and not as a biological entity in itself.

Wylie[7] was careful to point out in his paper on anteroposterior dysplasia that the assessment of dysplasia must involve not one but all three planes of space, and in that paper he dealt with the facial dimensions which have to do with depth. A study of Table I in this paper indicates that in the plane of space at right angles to the one considered by Wylie, the plane in which vertical dimensions are recorded, the absolute dimensions of height interact with one another to affect appreciably the esthetics of the face.

The first three values in Table I, measurements of total face height, upper face height, and lower face height, indicate clearly that in these facial patterns which have been labeled bad by virtue of the large Frankfort-mandibular plane angle, the facial pattern is disposed vertically, with the height of the face longer at the profile in individuals in whom this angle is steep than it is in individuals with more acceptable physiognomies. The progression of mean values from one group to another is sure and steady in total face height and in lower face height, but less so with respect to upper face height. This shows rather unmistakably that excessive vertical development of the alveolar process in the anterior segment of the denture is primarily responsible for the facial anomaly. This is further brought out by measurements taken from the incisal edge of the maxillary central incisors to the Frankfort plane and to the maxillary base, respectively, and by the measurement (G) from the incisal edge of the mandibular central incisors to the plane of the mandibular base.

These figures show that the facial pattern becomes worse as there is a vertical elongation in the anterior segment of the denture. This has important clinical implications, since cephalometric studies have shown that the depression of teeth, regardless of the segment of the denture involved, is extremely difficult. When the effort to depress teeth is made by means of ordinary orthodontic appliances, the depression of those teeth is pitted against the vertical development of teeth in other segments of the dental arch, and the vertical development or elongation of the teeth and alveolar process is the movement which predominates. Consequently, when it is determined that an undesirable vertical elongation of the denture in the anterior portion of the face is present, prognosis for attacking the problem directly is not good.

These measurements are concerned with height at the profile; measurements taken in the molar region to the Frankfort plane and to the planes chosen to represent maxillary and mandibular bases, respectively, indicate that the vertical elongation is limited primarily to the anterior portion of the denture rather than the molar area.

Finding that the profile is elongated in individuals with steep Frankfort-mandibular plane angles came as no surprise; on the other hand, it was fully expected that the length of the mandibular ramus as measured from the head of the condyle to the gonial angle (M) would have equal importance in the determination of the Frankfort-mandibular plane angle, i.e., it was expected that this ramus length would be relatively short where the angle was steep. As a matter of fact, before the Frankfort-mandibular plane angle came into use among orthodontists, reference was made at California to this type of case as "short ramus" cases.

The figures published herewith indicate that such an appellation was, always excepting individual cases, a misnomer. The lack of any significant downward progression of mean values indicates that there is not an inverse relationship between the length of the ramus and the magnitude of the Frankfort-mandibular plane angle as was supposed before the data were collected. It appears from these data, however, that an important qualification to that statement must be made. It would seem that the length of the mandibular ramus is of real importance where the Frankfort-mandibular angle is *small*. This suggests that orthodontists might consider the facial pattern characterized by a low mandibular plane angle as a distinct facial type in itself, with the primary factor responsible being more than average length in the mandibular ramus. Wylie[9] pointed out that there are essentially two classes of facial types in which the Frankfort-mandibular plane angle is relatively low. One must be regarded as a pleasing facial type according to present-day standards, for it is found frequently in the faces of professional models, particularly those whose services are sought by the so-called magazines of "high style." In these faces, besides the low Frankfort-mandibular plane angle, one may see the bony outline of the mandible sharply definite beneath the soft tissues, with a gonial angle approaching 90° and gonion itself prominent, with the posterior border of the mandibular ramus clearly discernible. In these faces the marked contribution to the facial pattern of a long ramus is obvious.

In the other class of facial types with relatively low mandibular plane angles, there is a severely closed-bite and the facial pattern cannot be considered good. Here, an increase in the vertical dimension brought about through orthodontic treatment brings a profound improvement in facial pattern. While these figures show that the actual length of the ramus from the head of the condyle to the angle of the jaw has less importance than was previously thought, at the same time the *effective* length of the ramus does play a significant part in establishing the Frankfort-mandibular plane angle. Brodie[10] was the first to indicate how anteroposterior placement of the glenoid fossa, determined by length in the cranial base, could affect the anteroposterior relationship of the dental arches. Wylie[7] allowed for the quantitative appraisal of this factor, and the use of his method reveals the importance of Brodie's concept. Item K in Table I shows that the location of the glenoid fossa in the vertical plane as related to the Frankfort horizontal plane has a definite influence upon the *effective* length of the mandibular ramus. The distance between the head of the condyle and the angle of the jaw may be sufficiently large to give good vertical proportions to the face; however, if the glenoid fossa is sufficiently high in the cranium, the effect will be the same as that produced by a short ramus, and, other things being equal, the Frankfort-mandibular plane angle will be steep. The definite progression of mean values after Item K shows that there is a definite relationship between the value of the Frankfort-mandibular plane angle and the placement of the glenoid fossa vertically in relation to the Frankfort plane.

When 150 cases are classified with respect to the size of the Frankfort-mandibular plane angle, a progression is also seen in the value of the gonial angle (L).

The fact that the gonial angle tends to be larger when the Frankfort-mandibular plane angle is large, and when there is more than average vertical development of the anterior portion of the face, leads to some interesting speculation. One wonders whether the gonial angle is large because there is an inherent tendency in the face of the individual to develop vertically at the profile, with gonial angle size adapting to this situation, or whether the fundamental reason for vertical development at the profile is adaptation of the facial pattern to an inherently large gonial angle. There seems to be no ready way in which this question could be settled definitively, but offhand it seems more likely that the height of the alveolar process is adaptive to an inherently large gonial angle. If the primary factor in the relationship were a tendency for alveolar development, adjustment in the posterior part of the face could be achieved simply through backward hinging at the temporomandibular joint, without any alterations in the magnitude of the gonial angle. This is but another instance in which the relationship between two variables may be observed, and in which it would be unwise to assume any cause and effect relationship.

It is probable that the progression which may be observed with respect to the Frankfort-maxillary base angle (O) may be explained on a basis of marked vertical development at the profile which has been mentioned sufficiently often in this paper. Note, however, that where the Frankfort-mandibular plane angle is less than 25° the mean value for the Frankfort-maxillary base angle does not form a part of the progression, lending further support to the concept that this is a more or less distinct type of face.

SUMMARY

The Frankfort-mandibular plane angle has been shown to be a valuable diagnostic criterion in the analysis of the facial pattern in orthodontic patients. It is not an anatomical entity, however, and in this study 150 patients have been classified with respect to the Frankfort-mandibular plane angle. An analysis of mean values for different dimensions of the face shows that a definite progression of mean values may be observed in practically all of the dimensions under study when facial patterns are segregated into different classes based on the magnitude of the Frankfort-mandibular plane angle. These progressions of mean values indicate that the Frankfort-mandibular plane angle is affected by vertical development of the alveolar process in the anterior portion of the denture, by the absolute length of the mandibular ramus, and by the inferosuperior placement of the glenoid fossa in the skull. It is furthermore shown that, statistically speaking, there is a direct relationship between the size of the gonial angle and the size of the Frankfort-mandibular plane angle. Where the Frankfort-mandibular plane angle is relatively small (i.e., less than 25°), a more or less separate and distinct facial type is encountered, which has special connotations in esthetics and in prognosis for orthodontic treatment.

This project was carried on under the direction of Dr. Wendell L. Wylie, while he was Chairman of the Division of Orthodontics at the University of California. Research funds provided by Dr. J. M. Loughridge, of Sacramento, Calif., were drawn upon for the support of this project.

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CARIES INCIDENCE IN RELATION TO ORTHODONTIC THERAPY

JOHN J. DOLCE, B.S., D.D.S., NEW YORK, N. Y.

IS THERE some verity to the generally accepted theory that prolonged orthodontic treatment means an increase in the number of cavities? If it is true, is it necessarily true? Is caries the uncontrollable effect of the other—orthodontic appliances? I believe these questions were in my mind since the early part of my orthodontic training. Experience proves that the general public almost unanimously accepts the premise that following the correction of a child's malocclusion it is always necessary to have extensive reparative work done by the family dentist. To many it is almost as certain to happen as it is to expect that a permanent tooth follows the deciduous tooth. This feeling, justified or not, can be found in the family dentist. He will often jokingly remind the orthodontist—and, incidentally, the one to whom he refers all his cases and into whose hands he would trustingly commit his own children for orthodontic care—that when the orthodontist is through he will place crowns on all the teeth or will refer the patient to an oral surgeon. It is meant to be humor. But it is not all fun—in the minds of both there is apprehension—there may be some truth in all this.

Can we prove that if old John Jones had not smoked as much as he did he might have lived beyond 100 years of age instead of passing away at 87? Can it be proved that overeating definitely shortened the life of Robert Smith? To be scientific it would be necessary to have these two characters relive their time in exactly the same manner, except for the one alleged culprit, i.e., smoking or eating. Would Mary Brown have had as many cavities if she had not been under orthodontic treatment for two years?

It is not simply a matter of yes or no to any one of these questions. The noticeable absence of literature on this subject of orthodontic decay attests to its complexity. It is almost difficult to understand why so little can be found in the dental literature. Perhaps many would be-investigators have felt it futile to attempt to prove anything conclusively.

The intention of any conscientious and honest practitioner in a specialized field is to investigate the true value of his efforts. He asks if he is doing everything possible for his patient's benefit. Could he do aything more? Is any harm being done? Can it be avoided or even minimized? Is it necessary? The orthodontist asks himself these same questions.

There is not much to be found in the literature of the last fifteen years. There are two or three investigators presently doing some private work, and

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they, perhaps, will bring some interesting facts to light. Each contribution of private investigation will be a step forward.

From the best scientific evidence available today it seems to be acceptable that caries of the enamel is principally a process of decalcification resulting from the acids of bacterial activity in carbohydrate food decay. Dental decay is now generally considered to be a disease of the calcified tissues of the teeth, caused by acids produced by the action of microorganisms on ingested carbohydrates. This was the theory of W. D. Miller a half-century ago, but his works were forgotten until recently. Most investigators concede that *Lactobacillus acidophilus* is the initiating force in the cycle of caries formation. These microorganisms, by their action on ingested carbohydrates, produce the acids which attack the calcified tissues of the teeth. Almost universally there are many microorganisms found in the mouth which, by their acids, are capable of decalcifying enamel. However, lactobacilli are the only microorganisms which have been found to show a significant increase in incidence with the initiation of caries. Lactic acid, the end product of the Lactobacillus acidophilus, has been present in carious regions. It is reasonable to state that because of the various investigations recently carried on, the lactobacillus count has come to be accepted as a significant index of caries activity.

Caries prevention has been the object of an unprecedented number and devious ways of experimentations. To date, these may be divided into three principal methods of control.

CARBOHYDRATES

The amount of food eaten by the average American has not materially changed in the last thirty years, but the amount of carbohydrate ingested has steadily increased until today the average meal is two-thirds carbohydrate. Although there is no conclusive statistical work done on this, it is generally assumed and conceded that the incidence of dental caries has increased with the times.

A number of investigators have shown and feel very strongly that the restriction of sugar in the diet is effective in caries control, and that a diet low in carbohydrates definitely reduces the number of acid-forming bacteria in the mouth.

Bunting some years ago stated: "Control the sugar habits of the child and you will most effectively protect him from dental caries." Dental caries is not a deficiency disease; it is a luxury disease.

L. M. Waugh has done outstanding work along these lines with the primitive Eskimos in Labrador, Alaska, and Siberia, in which he proved that the Eskimo children never have a single decayed tooth, and never a cavity, until they have received sweets. The more highly refined the sweets, the more potent they are for acid fermentation. His famous slogan is "An unsweetened tooth cannot decay." Dr. Waugh worked with a group of 57 Eskimos between the ages of 40 and 60 years and gave them sweets for a period of six weeks. None of these had any decay and not even a trace of lactobacilli in the saliva, and he was able to produce four cavities as an average in every mouth.

Some of the reasons for not using a low carbohydrate diet in caries-active individuals range from lack of interest or willingness to cooperate to inability to obtain the required meat, eggs, and other high-protein foods rendered unavailable by high prices.

FLUORIDES

Within the last half-century no other means of caries prevention has received more public notice than the use of fluorine. There are many investigators devoting their entire time to the study of this possible answer to caries control, and the entire country is well covered in these projects. The areas of the following cities are at present studying the possible advantages of having fluorine added to their community water supply: Newburgh, New York; Grand Rapids, Michigan; Evanston, Illinois; Marshall, Texas; Sheboygan, Wisconsin. At present, no investigator has stated, with sufficient evidence, as to what may be expected by fluorination of water. Many projects are in operation but several more years will have to transpire before it will be possible for us to draw any conclusions.

Some men point out that there seems to be a tremendous difference in the DMF rate in children of the same age group but who are living in a fluorine-free water supply as compared to a community in which fluorine is found in the water. The optimum amount of fluorine seems to be one part per million. In these communities examination of the children reveals that their DMF rate is between 50 and 60 per cent lower than the same age groups in children in a near-by community of the same economic level but whose domestic water supply is fluorine-free.

These children having a low DMF rate, and living in a naturally fluorinated water supply community, have been exposed to fluorine ingestion since birth, and the entire dentition, both enamel and dentine, has been affected by fluorine. It is the belief of some investigators that many years of artificial fluorination of the water, especially during the tooth formative period of the dentition, is the most beneficial and produces the best results. This has not been investigated over an extended period of time, but great possibilities are foreseen.

In many communities the fluorination of the water supply is neither natural nor, for the present, artificial. Until more extensive research is done on this problem and until more concrete deductions can be drawn from the results, communities will hesitate to do anything about their domestic water supply.

It is very natural to expect that out of the fluorination experiments would emerge a more simple and personal bit of research. This is the topical application of the fluorides. A 2 per cent solution of sodium fluoride is topically applied in a series of four treatments at intervals of one week. The teeth are first thoroughly scaled and polished and the sodium fluoride solution is applied. The success of this method is as widely acclaimed as any other single endeavor in dentistry. Claims of from 5 per cent to 50 per cent caries reduction have been theoretically established. To more conscientious investigators, the results of the research thus far accomplished have not been of a practical or dependable nature.

Fluorides have also been presented to the public in various other forms: incorporated in candies, chewing gum, tooth pastes, mouthwashes, and in many other ways.

The proponents of fluorides claim for it a double-action quality, namely, the inhibition of acid-forming bacteria and, in some way, the protection of the enamel of the tooth, making it resistant to dissolution.

Still another method of resisting or minimizing the effects of caries was brought forth in the Gottlieb theory. This, briefly, consists of the impregnation of the tiny channels of the teeth by some chemical agent, which prevents the entrance of the microorganism into the interior of the tooth.

AMMONIATED DENTIFRICES

These various foregoing methods of caries combat are much inferior to the ammoniated dentrifices in their appeal to the practitioner of dentistry. It seems to be the most universally accepted method thus far presented. This statement is not intended to mean that it is the most efficacious. From a practical standpoint, the carbohydrate-restricted diet, the application of fluorides, and the Gottlieb technique seem to be more trouble than the public will accept until, at least, the benefits of any one can be graphically proved to them. All conscientious and dental minded people use a toothbrush as an aid in maintaining dental health. The use of an ammoniated dentifrice is not any additional trouble to them. The public has been easily educated to its acceptance. A questionnaire sent to all dentists, with whom I have mutual patients, clearly fortifies this contention. Universally do they prescribe the use of ammoniated dentifrices, often in conjunction with the fluorine treatments and with carbohydrate restriction diets.

Early investigators, in an attempt to discover the inhibitor of lactobacillus growth, came upon ammonia as a factor which was to be further studied. The ammonium salt, which was found to be most satisfactory from the standpoint of stability and taste and odor, was dibasic ammonium phosphate. This substance was found most effective when combined with an antibacterial and antienzymatic substance, a synthetic urea compound. From experiments with varying proportions the best combination was discovered which would utilize the ammonia liberation of the dibasic ammonium phosphate and the antibacterial action of the urea compound. These two substances are believed to soften and change the substance of the dental plaque and form a buffer which neutralizes the acids formed by the bacteria. As with other methods, many investigators feel that, finally, a solution has been found for the caries problem. We have rather briefly covered the accepted causes of dental caries and some of the preventative measures.

Susceptibility to caries on the part of the patient is probably more important as a cause of enamel decalcification than anything we do, or the patient can do, to his teeth. When you have a child with a high susceptibility to caries, you have two strikes on you to begin with, as far as prevention of decalcification is concerned. There are other factors you must take into account, such as

genetic influence, dietary influence, type of saliva, childhood health, and mouth hygiene.

Since our problem concerns itself mainly with the relationship between orthodontic care and the incidence of caries, we shall consider mostly the following: presence of appliances, type of appliances, oral hygiene, cementations, and decalcification under and near bands and appliances.

I. THE PRESENCE OF AN ORTHODONTIC APPLIANCE

No one I know will foolishly claim that the presence of orthodontic appliances will ameliorate the caries incidence picture. This "foreign object" can very easily become the collector and protector of food debris in the mouth. A mouth free of any encumbrances such as appliances, bands, ligatures, prosthetic appliances, fillings, and bridges is much more likely to be cleaner and freer of the formation of lactobacilli.

II. THE TYPE OF APPLIANCES

The simplicity of design and construction is a very important adjunct. The appliance employing a greater number of bands, arch wires, and ligatures will render the mouth more susceptible to food debris deposits and more difficult to maintain in a hygienic condition. The bands used must be well adapted and must fit properly. The cementation process must be carefully done in order to insure a lasting fit. The more simply designed appliance will allow easier access in toothbrushing and its hygienic maintenance will be better assured.

III. THE LACK OF PATIENT'S HYGIENE

From the first appointment, oftentimes, the orthodontist is able to ascertain the degree of oral cleanliness the patient will be able to maintain. Instruction in proper toothbrushing is an important corollary to orthodontic therapy. Inevitable are the areas of decalcification around bands and appliances on the teeth of those patients who do not scrupulously brush their teeth after each meal. In addition to the patient's attention, it is necessary that, during each visit, the orthodontist carefully cleanse all the teeth with a rubber cup or porte polisher or any implement of his choice. The questionnaire, which I shall describe later, indicates strongly that the general practitioners wish their patients free of appliances at intervals of four to six months, for a thorough prophylaxis. Here we may mention the work of Sved which bears out the possible hazards of not insisting on the best cooperation from the patients.

IV. CEMENTATIONS

Some work has been done on the effect of cementation of bands on the enamel surfaces of the teeth. Lefkowitz and Bodecker showed in 1938-1940 that dyes were able to penetrate the enamel of dogs' teeth after having had bands cemented with zinc oxyphosphate cement.

They reported by this study, that dental cements etched (decalcified) the enamel surfaces of the teeth in vivo after the bands had been left on for several

days. It was discovered that ground or polished teeth were more susceptible to this etching than intact teeth, suggesting that there is a protective film on the teeth. This film is acid resisting and durable as reviewed in the literature by Chase (1926) and Bibby and Van Huysen (1933). The application of a collodion mixture, immediately prior to cementation, was definite improvement in the prevention of this etching.

By their study, Castello, Massler, et al., reported that all enamel surfaces exposed to the action of various mixes of cements were more or less affected. This etching appeared most severe in ground surfaces, indicating the presence of a "protective film." The degree of etching did not seem to increase after the cement was completely set, and it did not affect the collodion-treated teeth. Evidently, the enamel is affected during the setting time, and prolonged contact, after the cement had set, did not injure the enamel further. This would seem to indicate that it is a distinct disadvantage to cement the bands frequently.

V. WASHING AWAY OF CEMENTS

The orthodontist's one responsibility, and one which he cannot pass on to anyone else, is the condition of the cement under the bands. The most insidious and destructive type of decalcification can take place underneath a loosely fitting band. Besides the molar bands, which bear the strain of holding the appliances in place, the lingual surfaces of the upper anterior teeth are most often affected. The interval of time between cementing and recementing anterior bands is a matter of personal choice. However, the responsibility does remain to check each band for stability at every visit. Any washing away of cement from under the band demands immediate recementation.

QUESTIONNAIRE

As was mentioned in the opening sentences of this paper, I have often wondered about the relationship between orthodontics and the incidence of caries.

Routinely, full-series intraoral x-rays and photographs and gnathostatic model impressions have been taken for study and record purposes. To the best of our ability, patients were not started on their orthodontic treatments until the mouth had been thoroughly checked and treated by the family dentist. At the first appointment, the patient is informed that it will be necessary to make the regular visits to the dentist as he has been accustomed, or at least once every six months. The patient's hygienic responsibilities are brought to his attention and toothbursh technique is taught, if thought necessary.

The appliance of choice has been, for the most part, the twin wire mechanism, as taught by Dr. Joseph Johnson. Usually, we use four first molar bands, cemented with S.S. White Germical Kryptex. To these bands are attached removable upper and lower lingual arches and an upper twin wire arch. In about 35 per cent of the cases a lower twin wire arch was utilized for a part of the treatment. Usually, only the upper central and lateral incisors were banded with Johnson anterior bands. Occasionally, bands were placed on the lower six anterior teeth, particularly in extraction cases. All anterior bands are cemented with Stratford-Cookson zinc oxyphosphate cement. The patients are normally

DR. JOHN J. DOLCE
2922 GRAND CONCOURSE, NEW YORK 58, N. Y.
FOrdham 7-2922

Questionnaire

1. Was all operative work completed before_____ commenced orthodontic treatment on_____?
2. How many visits did_____make to your office between_____and_____?
3. What operative work was done at these visits—type of filling and its exact location?
4. Did patient have any prophylaxis during this time? If so, what are the dates?
5. Patient's orthodontic work was completed on_____ When was patient to your office after this date and what work was found necessary to be done?
6. Did you practice sodium fluoride immunization?
7. If not, do you do it now?
8. Do you prescribe ammoniated dentifrices?
9. If not, do you think the orthodontist should?
10. How often do you prefer to have all appliances removed?

Remarks—

Fig. 1.

DOCTOR JOHN J. DOLCE
2922 GRAND CONCOURSE
NEW YORK CITY
FOrdham 7-2922

February 1, 1950

Dr. Charles Jones
241 East 241 Street
New York, N. Y.

Dear Dr. Jones:

I plan to make a statistical study of a situation in orthodontics which is of great importance to the family dentist and the orthodontist. The thought exists that an increased need for operative work usually follows orthodontic treatment.

I have selected this subject for a thesis which I am to prepare, and would be most sincerely appreciative of your frank and honest reply to a few questions. I am similarly writing to the dentists of all other patients who have had an examination at the completion of the active phase of orthodontic treatment.

If I have failed to make any of the questions clear to you, please phone me.

Thanks ever so much for your cooperation.

Sincerely yours,

JD/hp
Enc.

Fig. 2.

seen every three weeks, at which time the arches are removed, the teeth carefully cleaned, and the bands checked for stability.

A questionnaire (Fig. 1) was made out for each patient who had been under full-term orthodontic treatment. These were mailed to the family dentist with a note from me (Fig. 2). It is quite understandable that I did not anticipate or hope for a complete and thoroughly accurate response. Many of these patients were under treatment, for part or all of the orthodontic treatment, during the war years. Many of them found it necessary to seek the services of a substitute dentist or, in many cases, several dentists. Consequently, many records have been returned incomplete or, in some, were not obtainable. We have used only the replies which we were reasonably certain were accurate.

CONCLUSIONS

A study of Table I indicates to me that the caries incidence in patients undergoing orthodontic treatment does not necessarily increase to alarming proportions. It is to be noted that a good proportion of the reparative operative work was done on premolars and second molars. These teeth had no bands or other appliances placed upon them. It is also to be observed that many of the first molar caries incidences were on the occlusal surfaces. A surprisingly small percentage of caries appeared on the labial and lingual surfaces of the banded anterior teeth as was also the case on the lingual and buccal surfaces of the banded first molars. It might be of some significance that twenty-four patients were and remained caries-free or had to have two or less new fillings inserted. These recordings were taken of all operative work necessary during the time of orthodontic treatment or within six months after the active orthodontic appliances were removed and the case was placed on retention. We are assuming, of course, that all incipient caries at the institution of active treatment was taken care of. It can also be reasonably assumed that a small percentage of caries was present in some cases at the start, and it must also be granted that a percentage of caries was not discovered by the family dentist until sometime after six months had elapsed after the cessation of active therapy. One situation may neutralize the other.

A study of Table II indicates the great interest the general practitioners have in the sodium fluoride and ammoniated dentifrices. This may be a very important factor in the immunization and resistance to caries formation. In the majority of cases the patients returned to their dentists for a thorough prophylaxis and fluorine or Gottlieb treatments. With but few exceptions, ammoniated dentifrices were prescribed by the dentists to all their patients.

The responsibility of the orthodontist is not contained within the field of appliance manipulation. As indicated by Tables I and II, most dentists express their desire to have the appliances removed every six months. The patient should then return to the dentist for thorough prophylaxis, x-ray examination, and treatments. The dentists unhesitatingly place this duty upon the orthodontist, and the orthodontist, in most cases, accepts this as his responsibility.

In conclusion, it would seem that, in view of the evidence of the returns just mentioned as a result of proper care and use of the various methods of

TABLE I

PATIENT	UPPER R 8	7	6	5	4	3	2	1 R	1	2	3	4	5	6	7	8 L	LOWER L 8	7	6	5	4	3	2	1 L	1 R	2	3	4	5	6	7	8 R
T. B.	o	mol			do				m	m		do		mod	mo	do		m	o	o							o	o	o	o	
A. B.			mo											mo															o	mo	o	
M. S.		o													o															o		
E. D.			o				m	d	d	m				o				o	o											o		
B. W.		o										do	mo		o					o										o		
R. F.					No work necessary																											
B. G.														o	o			o													o	
C. M.					Several occlusal fillings																											
R. M.		bo			do		dl					ext							mo	mo	mod	d				d	do					
P. M.		o				lab	lab			lab				o				o													o	
B. O.			o															mo														
J. B.		mod												do	mod			o	mo		o									bo		
																			db	o												
W. B.																		o														
D. G.			mo															o									do					
D. H.		md		m	m							d	do					o		do												
E. V.				do						l		d	mo		ob												o	mo			o	
J. C.	bo		mo				l					do		mo	b	o	o	o		do	mod									bo	mo	
J. G.	o	o												o	o			o	bo		o							do	mod	o		
S. U.	o	l													do			o														
T. M.				dm										mo						mo	do									do	o	
G. R.		o			do										o			o	o	o								do	do	o		
J. C.		o	o												o			o												o		
A. H.		lo										mod	m																			
T. H.			o											o				mo	do										o	b		
H. J.				o									mo	mo	o																	
A. R.			o	do	do							do	md					o		b										o		
B. N.			mo					mo					o	mo	o																	
M. M.														o				o												o		
V. R.			mo	mod		d		m	m				do		mo					mo					b					mob		
O. I.					No cavities on permanent teeth																											
M. R.		o	do										do		o																	
B. M.	d	dm	m															o	o											o		
A. F.			mo																													
J. A.		o													o																	
T. A.		bo	o	do								o			o			o												o		

| | | |

TABLE I—CONT'D

PATIENT	UPPER R 8	7	6	5	4	3	2	1	L 1	2	3	4	5	6	7	L 8
T. F.			mol											mo		
E. H.			mod	do	do							o	do		o	
D. L.			o											o	o	
T. W.		o		mod	o				l				o		o	
N. K.							RC						mod			
P. S.																
J. G.		lo		o								do	o		lo	
D. D.					No work necessary—caries-free											
J. D.			mo											li	o	
M. S.																
M. G.					No work necessary—caries-free											
J. W.		bo										do			dbo	
M. L.			o											o		
E. M.		do	o			d				d			d	o	bo	
H. Q.	o														b	o
L. Y.											lab					
J. G.					Caries-free											
V. G.					Caries-free											
J. M.			m	do			m		m				do		b	
J. M.														o		
J. D.		o														
A. M.					No decay—caries-free											
E. S.			m								d				do	
J. P.			o				m							o	o	
M. G.			lo		o											
G. S.																

PATIENT	LOWER L 8	7	6	5	4	3	2	L 1	R 1	2	3	4	5	6	7	R 8
T. F.		o	bo								m			bo		
E. H.		o	o	o								do	do	mod	bo	
D. L.		o													o	
T. W.		o		do								o		o		
N. K.																
P. S.										d				do		
J. G.		bo		o								do	o	o	o	
D. D.																
J. D.				ml										ml		
M. S.			o		pits									o		
M. G.																
J. W.		o														bo
M. L.			o											o		
E. M.		o	o	do										bo	o	
H. Q.								dm				mo	do	o	o	
L. Y.														lo		
J. G.																
V. G.																
J. M.		mo	mo		b								do	m		
J. M.			o											o		
J. D.		o													o	
A. M.																
E. S.																
J. P.		o	o											mo		
M. G.		b													bo	
G. S.			do													

TABLE II. ANSWERS TO QUESTIONS

DENTISTS	NO. 4	NO. 6	NO. 7	NO. 8	NO. 9	NO. 10
E. G.	No	No	No	Yes	Yes	--------
A. R.	--	No	Yes	Yes	Yes	Yearly
W. Q.	No	No	No	Yes	No	--------
T. W.	No	No	No	Yes	No	3 months
W. H.	Yes	No	No	Yes	--	Yearly
G. P.	Yes	No	No	Yes	--	4 months
H. W.	No	No	Yes	Yes	--	6 months
L. B.	No	No	Yes	Yes	--	6 months
E. Z.	Yes	Yes	Yes	Yes	--	--------
I. B.	Yes	No	No	No	--	--------
W. D.	Yes	Yes	Yes	Yes	Yes	4 months
M. W.	Yes	No	No	Yes	--	Yearly
W. G.	No	Yes	Yes	No	No	3 months
G. L.	Yes	Yes	Yes	Yes	--	6 months
B. W.	Yes	Yes	Yes	Yes	Yes	--------
H. H.	No	No	Yes	Yes	Yes	6 months
B. B.	No	Yes	Yes	Yes	Yes	Yearly
F. C.	Yes	No	Yes	Yes	Yes	--------
R. F.	Yes	No	Yes	Yes	No	6 months
I. A.	No	No	Yes	No	No	6 months
P. F.	Yes	No	Yes	Yes	Yes	3 months
W. W.	No	No	Yes	Yes	Yes	6 months
M. B.	No	Yes	No	Yes	--	6 months
S. P.	Yes	No	No	Yes	--	--------
M. B. M.	No	No	Yes	Yes	--	Yearly
A. M.	No	Yes	Yes	Yes	--	6 months
M. D.	Yes	No	Yes	Yes	--	4 months
F. M.	Yes	No	Yes	Yes	Yes	--------
L. S.	No	No	No	Yes	--	--------
L. R.	Yes	No	Yes	Yes	Yes	3 months
L. R.	Yes	No	Yes	Yes	Yes	6 months
H. P.	No	No	Yes	Yes	Yes	6 months
H. Y.	No	No	No	Yes	--	6 months
J. O.	Yes	No	Yes	Yes	Yes	6 months
E. B.	--	No	Yes	Yes	--	6 months
T. M.	No	No	No	Yes	Yes	6 months
S. K.	Yes	No	Yes	Yes	Yes	Yearly
J. V.	No	No	No	No	--	6 months
V. K.	Yes	No	Yes	Yes	--	6 months
C. M.	No	No	Yes	Yes	--	6 months
R. C.	No	Yes	Yes	Yes	--	6 months
J. F.	Yes	No	No	Yes	Yes	3 months
O. R.	Yes	Yes	Yes	Yes	--	6 months
T. H.	Yes	Yes	Yes	Yes	Yes	6 months
D. P.	Yes	No	No	Yes	--	4 months
A. C.	Yes	Yes	Yes	Yes	--	6 months
E. W.	Yes	No	Yes	No	No	6 months
B. B.	Yes	No	No	No	No	--------
S. P.	Yes	No	No	No	No	Yearly
I. G.	Yes	No	Yes	Yes	--	--------

caries preventives, one can state with safety that caries incidence is not necessarily greatly increased because of orthodontic appliances. However, if not placed with exact care and not periodically checked and cleaned, appliances will almost always be a causative agent.

Just as that which is an approximate occasion of sin must not be judged to be the sin itself, so may orthodontic appliances be an influence in caries incidence (if poorly cared for), but not necessarily the cause.

2922 GRAND CONCOURSE.

A Digest of "A Challenge to the Profession"

MORE discussion about the general practitioner being better trained and practicing orthodontics is heard today than has been heard since the turn of the century, when appliance manufactures were regaling the dental profession to take up the treatment of malocclusion using prefabricated appliances with clamp bands, dual purpose buccal tubes, and 16-gauge threaded arch wires.

Writing in the *Australian Journal of Dentistry,* February, 1950, under the title of "A Challenge to the Profession," Kenneth T. Adamson, D.D.S., Lecturer in Charge of Orthodontics, University of Melbourne, reveals some interesting views in regard to future orthodontic practice and the position of the general practitioner in the picture. It is appropriate at this time to quote at length from this interesting paper.

Dr. Adamson says that in Australia, "particularly during the last eighteen months the attention of the dental profession has been focused on the Federal National Health Plan, which is to include a Dental Health Service. The present intention would seem to be that this will begin with the pre-school age child, and gradually be extended to adolescents." He quotes the English orthodontist, Russell Logan, "In any scheme designed to promote and maintain the health of the community, orthodontics, which is directed toward establishing the efficient mechanical structure of the teeth and jaws, must be one of the fundamentals." This envisages the necessity for many more people becoming interested in the subject than there appear to be at the present time. "Interest does not necessarily imply specialization," he says, "but an intelligent appreciation of possibilities. Orthodontics has made good progress during the last fifteen to twenty years, perhaps more than any other specialized branch of dentistry. This period has witnessed a complete revolution of thought, so that what was once regarded as merely a mechanical problem involving the movement of teeth, has now become a biological one, with all the intriguing factors of growth and development of living tissues."

Dr. Adamson suggests a scheme whereby an adequate orthodontic service can be provided for all who wish to avail themselves of it, and he further points out that in his opinion the responsibility for providing orthodontic treatment rests with the general practitioner and also the specialist. "A close and understanding cooperation between these two can, and should, provide a type of service to suit any purse," according to Dr. Adamson.

To quote the author further:

"This still leaves untouched the large mass of public who are unable to pay any fee, and who must receive treatment from a public institution such as the Dental Hospital, or, perhaps eventually under some State or Federal dental health scheme. At present the service provided for this section is totally inadequate. Whether the patient is paying for treatment or not, it does not alter the fact that the responsibility for orthodontic treatment will still be shared

by the general practitioner and specialist, the only difference being that in the latter case both will be paid by a public institution or by the Government."

The author agrees that orthodontics is a highly specialized subject but contends nonetheless that every undergraduate must be trained in fundamentals and to carry out simple treatment of cases and know diagnosis well enough to advise parents.

"To encourage untrained, or partly trained, men to use fixed appliances will do more harm than good, and why should it be necessary? It has never been suggested in medicine that every doctor should become a surgeon to cope with the mass of surgical cases which present for treatment. In country towns where distance makes it impossible for all patients to be referred to the city, one finds that a particular doctor combines a great deal of surgery with his general practice, and will undertake most surgical cases, but he rarely does this without preparing himself by attending several post-graduate courses. Any general dental practitioner could, and should, fill a similar role in any country town by carrying out orthodontic treatment with his general practice, if he is sufficiently interested to give up the time for post-graduate study."

Dr. Adamson quotes Mr. Heath: "Knowledge of the changes that occur with growth in the face and dental arches, and the stage of growth expected for any given age and sex must be part of the equipment of every dentist who would practice any phase of orthodontics.

"This we firmly believe. There is no short cut, no easy method for learning essentials, and experience must be acquired to apply them, but the result is worth while. The following reasons which Mr. Heath advances, in the arteile previously quoted, for the failure of orthodontic teaching are so obviously inaccurate says the author that they call for special comment.

"(a) It has been incorrect that Brodie and others have disproved the teaching of Angle.

"This statement seems to infer firstly that Angle's theories are all that are taught in dental schools today, and secondly that Brodie has proved all that Angle taught to be incorrect. In actual fact, Angle's work forms only a part of the orthodontic curriculum in any dental school.

"Angle made two great mistakes, but remember, he wrote thirty or more years ago, and without any modern scientific aids to help him. He taught that the restoration of 'normal function' of the jaws would bring about normal growth and development of the supporting base, since disproved by Brodie. He also thought the mandible was distal to skull anatomy in Class II cases because it was underdeveloped.

"The first led him to strongly oppose extraction as part of orthodontic treatment, and he preached that such a procedure amounted to orthodontic heresy. Since recent research has proved this part of his teaching to be incorrect, leading Angle followers in the world are today extracting in as many as 65% of their cases."

About fixed appliances, Dr. Adamson says:

"The dangers accompanying any tooth movement are well known, death of the pulp, resorption of root apices, and resorption of the labial or buccal plate of the alveolus, with its accompanying recession of the gum.

"Admittedly in untrained hands fixed appliances are difficult to manage and certainly dangerous, but this only strengthens our claim that a post-graduate training of at least six months is needed to handle any one of them. Any type of orthodontic appliance is dangerous if it is not understood, even a removable appliance but particularly those fixed appliances."

As to orthodontic teaching, excerpts from the text follow:

"Is there then justification for the general condemnation of orthodontic teaching? The policy adopted by all schools is quite clear, viz., to train the graduate in all the fundamentals of orthodontics so that he can practice it in all phases except that of advanced fixed appliances. Those who desire to become proficient in this department must be prepared to take a post-graduate course of intensive training for six to twelve months. In most schools this is freely available.

"We believe this is not only a sound policy, but a safe one, and on this basis alone are we prepared to discuss the problems confronting us in mass orthodontics.

"Any plan of attack on malocclusion must begin with the general practitioner, for it is he who first sees the patient with the malocclusion in its initial stage. In discussing treatment we should be quite clear in our minds just what we are trying to achieve. Earlier we have stated it to be the production of a masticatory apparatus of maximum functional efficiency, which means a dentition which will keep itself clean from food debris, grind the food with efficiency, and by continual vital processes adjust itself to compensate for wear and tear throughout the life of the individual (Logan). We believe that the hope of achieving this object lies more in denture guidance than in denture correction, and as long as the profession continues to ignore some of the simplest and best-known preventive methods.

"For many years orthodontists have preached the necessity for keeping the deciduous dentition healthy, functional and efficient, if the patient is to have any chance of attaining normal occlusion. They have also taught that the premature loss of deciduous teeth must produce a malocclusion unless steps are taken to prevent it. In some cases this is the sole cause of malocclusion, and, in others which have their origin in inherited or evolutionary factors, it greatly adds to the confusion which already exists. What is the use of discussing methods of combating the ever increasing number of malocclusions if the profession is daily creating them in practice?

"We realize that it is sometimes difficult, or well-nigh impossible, to sell such ideas to the general public, mainly because the public itself is so woefully ignorant on the subject. We are desperately in need of an inspired drive to enable the public to appreciate good dentistry. It is unfair to expect the dentist to be entirely responsible for this, although in many cases he does his best. In Victoria the body which should be responsible for such propaganda, namely The Dental Board, appears to have little interest in this aspect of public education. We feel that they would be serving the interests of the profession more adequately if they were to devote their attention to this most important subject, and leave he post-graduate training of dentists to the

Australian Dental Association (Victorian Branch), which already has a Committee formed for that purpose. The Dental Board's first concern should be the relationship between the dentist and the public, and by educating the public in matters of dental health—particularly in reference to children, they will make it much easier for the profession to do everything within its power to preserve a healthy condition in the mouths of the children."

The author expresses his views on the ever-present question of the extraction of children's teeth, asking the question, "How many extract teeth without thinking of the result on the denture?" Then he quotes the French orthodontist Delabarre in 1815 as saying, "It is much easier to extract teeth than to determine whether it is absolutely necessary."

"The extraction of a tooth requires nothing more on the part of the practitioner than a degree of facility in the use of instruments that are usually employed in this operation; whilst the knowledge necessary to appreciate the consequences can only be acquired by time and study." This is just as true today.

"Do you think that very many dentists when they see a malocclusion try to work out the cause? If the upper incisors are beginning to protrude, do they consider lipsucking or thumb sucking? Or, when there is a space between the upper or lower incisors, do they suggest to the parents that the child may be lisping, chewing a pencil or that he has some tongue habit? We are afraid that in many cases these things go unnoticed and unsung.

"This is the greatest argument in favour of an organized service for children, where it will be possible to make certain that all the personnel are so trained that they will be able to give an orthodontic evaluation of the mouth along the lines we have already outlined.

"For those of you who have forgotten some of your early training, it is hoped that very shortly a series of articles will be published which will act as a refresher course. To those who have had the advantage of more recent training, we urge you to honestly and sincerely apply what you have learned.

"So we may say that the basis of our scheme must be prevention, and this must be practiced by the general practitioner. The specialist is always available for advice, and he will be only too pleased to help in those cases in which there is any doubt about the correct procedure.

"When we come to consider treatment from the manipulative point of view, we find that all cases of malocclusion naturally fall into five groups, which may be listed as follows:—

"**Group 1.**—Those in which the early elimination of a bad habit will be sufficient correction.

"**Group 2.**—Those in which extractions alone will produce a satisfactory result. Malocclusions in this group will be Class I (Angle).

"**Group 3.**—Those in which a simple removable appliance will produce a satisfactory result. Malocclusions in this group will be Class I (Angle), including closed bite cases (with large freeway space).

"**Group 4.**—Those in which extraction plus a simple removable appliance will give a satisfactory result. Malocclusions in this group will be Class I (Angle), Class I (Angle) with upper mesial and normal depth of overbite.

"**Group 5.**—Those in which fixed appliances will be necessary to produce a satisfactory result. Malocclusions in this group will be:—

"Class II cases (Angle).

"Class III cases (Angle).

"Class I cases (Angle), with 'closed bite' due to elongation of upper or lower incisors or both. Freeway space small.

"Class I cases (Angle), open bite (local).

"Class I cases (Angle), upper mesial (closed bite).

"From this classification it will be seen that it is necessary to be able to classify cases according to the Angle classification, if the general practitioner is to be able to distinguish between those cases which he is competent to treat and those which he is not.

"The average man often thinks this is something which is quite beyond him, but once it is understood it is very easy. It is something like learning to ride a bicycle or to skate—difficult at first, but once mastered is never forgotten.

"Once having clarified our minds as to the type of case to be treated, the next question which we must ask ourselves honestly is: 'Are we capable of handling this case?' Generally speaking, any case which falls into Groups 1, 2, 3 and 4 should be within the scope of any practitioner who has taken the trouble to master the principles involved in carrying out the work efficiently.

"The 5th Group comprise those more difficult cases which require treatment with fixed appliances, and must be handled by those who have undertaken additional training in the use of these appliances.

"We have made our policy quite clear—we do not favour the general use of fixed appliances by the profession as a whole. In private practice this probably means referring the case to a specialist, or, perhaps to a dentist in general practice who has undertaken post-graduate training. In any organised State or Federal Scheme it would mean the training of sufficient men as specialists to work hand in hand with the general practitioner who should have received adequate training in diagnostic and preventive orthodontics.

"Examining the question from the financial aspect, it will be obvious that the fewer Group 5 cases we have to deal with, the more economical will be the scheme, for these are the cases which take a long time in treatment, and time means money. If by the application of recognised preventive methods we are able to reduce the number of severe malocclusions by 50%, and this could be done, we will have saved a great deal of both time and money.

"Summing up the position we find that:—

"(1) Malocclusion in the present-day child is increasing.

"(2) While many of these malocclusions have their origin in factors beyond our control such as heredity, evolution, etc., quite a large percentage are caused by bad dentistry and could be avoided.

"(3) Any dentist who works on children has a responsibility to the public to see that he has the requisite knowledge to give his child patients the best possible service, and this means that he must be able to (a) recognise incipient deformity, (b) understand the etiology of deformity, (c) institute preventive measures, (d) perform simple corrective measures.

"(4) In addition to the general practitioner, who is able to perform this service, there must be a group of more highly-trained men capable of treating any type of malocclusion with fixed appliances, and who will be available for consultation with the general practitioner in the more difficult cases. The best results can only be obtained by close co-operation between the general practitioner and the specialist.

"(5) There must be a completely changed outlook on orthodontics. We must cease to think of it as a purely mechanical problem, and must regard it as a biological one.

"Sound advice or a simple guiding device used early are more beneficial than the most skilled use of a complicated corrective appliance. As we have already said, part of the problem is to educate the public to appreciate prevention rather than correction. Once they are convinced, parents will be willing to bring their children for early advice and denture guidance. Preventive orthodontics becomes more of a reality as our knowledge of skull growth increases, thanks to the introduction of cephalometric x-rays.

"The future of children's dentistry constitutes the challenge to the profession. Surely the coming citizens of this country are worthy of our best efforts, but we must begin NOW!"

Department of Orthodontic Abstracts and Reviews

Edited by
Dr. J. A. Salzmann, New York City

All communications concerning further information about abstracted material and the acceptance of articles or books for consideration in this department should be addressed to Dr. J. A. Salzmann, 654 Madison Avenue, New York City

Heredity, Environment, and Evolution: By Th. Dobzhansky, *Science* **111**: 161-166, Feb. 17, 1950. (Quoted, with deletions, from original article.)

"Genetics has been defined by Bateson as a study 'of the phenomena of heredity and variation; in other words . . . the physiology of descent.' Heredity, variation, and descent are aspects of the same basic phenomenon, although superficially they may seem distinct or even antagonistic. It is a matter of observation that children resemble parents, and this resemblance is ascribed to heredity. The resemblance is, however, not absolute, either between parents and children or among sibs. This is called variation. When we find, through observation or inference, that the organisms living now came from ancestors different from them we speak of evolution or descent.

"A man may resemble his mother in some respects or 'traits,' his father in other traits, and be unlike either in still others. It looks as if what is inherited is not a general likeness but rather resemblance in different particular traits. In common as well as in scientific parlance, such human traits as skin color, eye color, hair form, and head shape are considered hereditary. No abstruse analysis is needed, however, to show that a 'trait' is merely an abstraction useful for purposes of description, and as such cannot be inherited. An individual arises from the union of an egg contributed by the mother with a spermatozoon contributed by the father. These sex cells have no eyes, no hair, and no skin color. But a fertilized egg does develop, by means of a long series of very complex transformations and through many successive stages, into an organism which has eyes of a certain color, hair of a certain form, a more or less pigmented skin, etc. Furthermore, the traits or characteristics of an individual organism at any stage of its development are related to, and are to a certain extent predictable from, a knowledge of the traits of its parents and other ancestors. It is evident that what is inherited is a dynamic pattern of developmental processes which charts the course of the transformations of the body from fertilization to birth, to adulthood, and to death.

"This charting, however, does not amount to anything like complete determinism. It is well known that the course of development is influenced by the environment. Therefore the outcome of development at any stage is a function of both the heredity of the developing individual and the environment in which the process has taken place. Heredity does not determine traits; it determines, according to the somewhat awkward expression proposed by the Danish biologist Raunkaier, the 'norm of reaction' of the organism to the environment.

"Different environments evoke different reactions in organisms with similar heredities; different heredities engender different reactions in organisms which develop in similar environments. It is therefore obviously necessary to distinguish the outcome of development from its cause. Johannsen proposed to designate the former as the *phenotype* and the latter as the *genotype*. The

phenotype comprises all external and internal structures and functions of the organism. It can be studied and described by morphological, anatomical, and physiological methods. The genotype of an individual is the sum total of its hereditary properties. Examination of the pedigree, or of the progeny, or both, is needed to study the genotype. The phenotype of an individual changes continuously as the development proceeds, and, in fact, never becomes fixed. A series of photographs of a person taken at different times, from birth to maturity, old age, and death, illustrates the changeability of the phenotype. The genotype is relatively stable; the nature of this stability will be discussed.

"It is a widespread misapprehension that hereditary traits are independent of the environment, and that traits subject to environmental modification are *ipso facto* not hereditary. On the contrary, no organic form or function can develop except as a response of a certain genotype to a certain environment. The so-called 'nature-nurture' (genotype-environment) problem is not to distinguish which traits are genotypic and which are environmental, for all traits are genotypic and environmental. The problem is to what extent the actually observed variability in individuals of a species (such as man) is caused by the available variety of genotypes, and by the existing variety of environments. In this sense, the relative importance of genotype and of environment is quite different for different traits. For example, the blood group to which a man belongs seems to be fixed by his heredity; no method of changing the blood antigens is known at present. The skin color depends both on the genotype and on the exposure of the skin to a certain part of the ultraviolet spectrum. Man's behavior is supposed to conform to circumstances, i.e., to the environment. But it is easy to show that behavior is influenced also by the genotype. For example, a man with a black skin (a genotypic trait) will, in a 'color conscious' society (environment), evince a different behavior (phenotype) from a man with a light skin. The fact that in different social environments these men's behavior might be alike, or reversed, does not make the behavior independent of the genotype.

"The relative importance of genotype and of environment in the determination of the developmental pattern is not unalterable. If the environment becomes standardized, the variability of genotypes increases in importance. Environmental agents become more influential when they grow stronger or more diversified, or when the organisms on which they act are genotypically uniform or nearly so. Now, man creates new environments and is therefore potentially able to augment or diminish the rigidity of genotypic determination. It is clear that the development of an individual is an orderly sequence of physiological and, ultimately, physicochemical reactions in which the genotype and the environment are involved. If a detailed knowledge of these reactions were available, the phenotype would be under our control to a much greater extent that it is now. As Goldschmidt has pointed out, any change in the phenotype produced by a variation of the genotype could, in principle, be produced by environmental influences as well. Although this presupposes a more nearly perfect knowledge of development than is actually available, the principle is valid. Medical treatment of hereditary disease or, indeed, of any other disease consists essentially in placing the patient in environments so contrived than his genotype reacts by engendering a phenotype which is regarded as desirable. Medicine and pedagogy are, from the standpoint of genetics, sciences of management of the human phenotype. Heredity is often spoken of as 'destiny.' It is destiny largely in proportion to our biological ignorance.

"The foremost problem of genetics has been to investigate the structure and the operation of the genotype in individual and in evolutionary development. To date, the greatest discovery in this field has been that made by

Mendel. Mendel demonstrated that the genotype is not a diffuse continuum, which it was believed to be before Mendel (the 'blood' theory of heredity), but a sum of discrete particles, now called genes. The rules of the transmission of genes from parents to offspring have been established by means of a certain powerful analytical tool, invented by Mendel and perfected by his successors. This tool is hybridization of varieties of plants or animals which differ in some known respects; the distribution in the offspring of the traits in which the parents differed is followed one by one, and is recorded quantitatively. The rules discovered by Mendel enable biologists to make sense of a great mass of otherwise chaotic data; they also enable geneticists to devise new experiments and to predict their outcome. The gene theory has been established without the genes' having been seen under the microscope, just as chemical reactions have been understood in terms of molecules and atoms without molecules and atoms' having been seen.

"The next step was made by the combined efforts of many brilliant men, among whom Weismann and Morgan were most important. This was the demonstration that the genes, or most of them, are carried in the microscopically visible chromosomes. The gene ceased to be merely a symbol; it became also a material particle. But the structure and the method of action of the gene still remained conjectural. The next advance, due again to collective achievement of numerous workers, among whom Muller has been most prominent, is now in process of accomplishment. Although many loose parts of the story still remain to be tied together, it seems most probable that the gene is a single molecule of nucleoprotein, or a part of a supermolecule, the chromosome. Some genes occur, however, in the cytoplasm also. There has developed, moreover, a most intriguing zone transitional between, first, cytoplasmic genes, which are necessary parts of a cell of a given species, second, viruslike symbionts which may or may not be present, and, finally, parasitic viruses which are transmitted from individual to individual not by heredity but by infection. A chromosome proves to be not a fortuitous assemblage of independent genes, but an organized system; the precise nature of the interrelations of the genes carried in the same chromosome is, however, still problematic. Whatever it may prove to be, heredity is a process enacted primarily on a molecular level inside the cells, and secondarily magnified to those macroscopic dimensions in which we are accustomed to observe the outcome of heredity.

"A human egg cell is estimated to weigh about one millionth of a gram. The increase in weight from egg to adult is, accordingly, some fifty billion fold. The source of the material for this enormous growth is not far to seek. It is the food and water consumed and assimilated by the organism. The development of any organism involves, then, transformation of materials withdrawn from the environment into a likeness of the assimilating organism and of its ancestors. Heredity is a process whereby the organism reproduces itself by consuming a part of its environment. This is especially obvious when we observe living things giving rise to progeny. But self-reproduction takes place in any living body. Experiments with isotopes have shown an amazing lack of permanence of most of the adult mammalian body; many body constituents are periodically broken down and reconstructed anew from food materials. Heredity is, fundamentally, self-reproduction.

"The units of self-reproduction are genes. Construction of their own copies is the most important and possibly the only function which the genes perform. . . .

"The essence of the process is that two gene molecules are formed where only one was present before. Whatever the chemistry may prove to be, the process is cyclic, and it is this cyclic nature that makes heredity possible.

". . . The germ plasm is the genic materials which reproduce themselves; the somatoplasm is produced in the process of gene self-reproduction. The 'stability' of the genes is peculiarly dynamic—they change to produce their own copies. Self-reproduction is the fundamental quality of life that distinguishes it from inanimate nature. This explains the apparently paradoxical nature of life: life changes the environment and is changed by the environment, and yet it preserves an inner continuity which is, in fact, its basic property.

"Every organism can exist in a certain range of environments and can subsist on a certain range of food materials. . . . The genes are, nevertheless, not unchangeable. In fact, they can be changed quite readily. . . .

"As a consequence, three kinds of changes in the genes can be visualized: (1) Changes that make the gene unable to reproduce itself. . . . This is doubtless the most frequent kind of change, which leads to losses of genes. (2) Changes that permit self-reproduction to occur, but that are not incorporated in the reproduction process. . . . Such changes are ephemeral, and are not detected by genetic methods. . . . (3) Changes that allow self-reproduction to continue and that are reproduced, or copied, in the daughter genes. Such changes are permanent and stable, in the same sense in which the ancestral gene structure was called stable. These are the mutations of genetics.

"Several environmental agents that speed up the mutation process are known: x-rays, ultraviolet radiation, high temperature, and certain chemicals. The effects of these agents are, however, unspecific, in the sense that they enhance the probability of occurrence of mutations of all kinds (although not necessarily to the same extent). In the last analysis, every mutation is caused by environmental influences, and there is no theoretical reason why geneticists could not eventually learn to induce at will specific mutations in specific genes. Such a feat may already be within our grasp in the type transformation of pneumococcus bacteria. But the interpretation of these transformations is not yet quite clear and, undeniably, complete control of the mutation process is still not in sight.

". . . We have seen that a gene encroaches on the environment and transforms a part of it (food) into copies of itself. The efficiency of this process may be described in terms of the number of copies (progeny) created per unit of time. The greater the surviving progeny of an organism, the better this organism may be said to be adapted to a certain environment. The process of differential perpetuation of different genes and genotypes is Darwinian natural selection. With respect of adaptedness, or fitness, three types of mutations may be distinguished.

"(1) The adaptedness of the mutant is lower than that of the ancestral form in all existing or attainable environments. . . . Inasmuch as the outcome of selection is in this case elimination of the mutant and preservation of the original type of gene or organism, this form of selection is a conservative force. . . .

"(2) The adaptedness of the mutant is higher than that of the ancestral form in all environments the species occupies or can reach. The outcome of the process of natural selection will here be the converse of the preceding case: the ancestral type will become extinct, and the environment will be monopolized by the mutant. An evolutionary change will have taken place, because a previously existent type is replaced by a new one.

"(3) The adaptedness of the mutant is higher than that of the ancestral type in some environments, but lower in other environments. The process of natural selection will in this case lead to elimination of neither the mutant nor the original type. Instead, the outcome of selection will be establishment of an equilibrium state, at which both the old and the new types of organization will continue to exist. The numbers and relative frequencies of the two types

will depend upon the abundance of the two kinds of environments in the world and upon the absolute reproductive efficiencies of the two types of organisms involved. The outcome of natural selection will thus be a diversification of the organisms existing in the universe. Two types will occur where only one lived before the change took place. This is the dynamic form of natural selection.

. . . . . .

". . . In organisms other than viruses, the genotype is an integrated system of many kinds ('loci') of genes. Estimates of the numbers of gene loci in higher organisms are of the order of thousands or tens of thousands. Most or all of these loci change from time to time by mutation, and are represented in populations of a species by different variants ('alleles'). The constellation of gene alleles that an individual has consists of genes it has inherited from its ancestors or acquired by mutation of the inherited genes. The genes do not determine parts of the body, organs, traits, or even independent physiological processes. The entire genotypic system defines the matrix of the development of the organism as a whole. The development is apparently epigenetic, not preformistic, although preformism appeals to the thinking of many biologists, and many overtly or covertly preformistic theories are still current in biology. In any case, it is generally agreed that the adaptive value of a genotype in an environment is a property of the genotype as a whole, and not a simple sum of the values of its constituent genes. A gene, *A*, may be deleterious in combination with *B*, neutral with *C*, and useful with *D*.

"Mendel showed that the variety of genotypes created in the process of sexual reproduction is staggeringly great. . . . Sexual reproduction is an unbelievably efficient trial and error mechanism because it creates countless new genotypes to be tested by natural selection. Because of the high efficiency of sex in the performance of this biological function, sexual reproduction has become established in most organisms as the normal method of propagation. Natural selection has evolved and perfected sex because it proved to be a basic adaptation which makes other adaptations more readily available. One of the most ridiculous features of the 'dialectical' theory of Lysenko is his belief that the magic of sex 'invigorates' the organism; his rejection of the gene theory has landed Lysenko in primitive animism. He fails to understand that it is the relative stability of genes that makes life possible, but that the stability is combined with a remarkable freedom in the creation of new genotypes in the process of sexual reproduction. The conservatism of heredity is balanced by the creativeness of sex.

. . . . . .

"Mutations are, in the last analysis, physicochemical alterations in the genes or chromosomes; hence they cannot be wholly independent of the environment. . . . The environment prevailing at the time mutation takes place is only a component of the environmental complex that determines the mutation.

". . . A mutation is, in general, reversible and recurrent; in other words, the gene *A* mutates from time to time to *a*, but *a* mutates back to *A* with an equal or different frequency. If the gene *A* is adaptive in summer, for example, and *a* adaptive in winter, the selection favoring *A* during one season may be undone during the next season. But when many genes have mutated, and when natural selection has established a new and harmonious genotype including these mutants, the probability of reversion or of repetition of the process becomes negligible. Evolution becomes irreversible and unrepeatable as it ceases to be a physiological process and becomes a historical process.

"Based on an address read before the joint meeting of Section L of the American Association for the Advancement of Science, the American Philosophical Association, and the Philosophy of Science Association, on December 30, 1949, in New York City."

News and Notes

American Board of Orthodontics Case Report Display

Exhibit of case reports submitted by applicants for certification by the American Board of Orthodontics, Saturday, May 7, 1950, in Chicago at the Edgewater Beach Hotel.

Central Section of the American Association of Orthodontists

The 1950 meeting of the Central Section of the American Association of Orthodontists will be held November 26, 27, and 28 at Cedar Rapids, Iowa.

Great Lakes Society of Orthodontists

The Great Lakes Society of Orthodontists will meet at the Statler Hotel, Detroit, Mich., on Nov. 20, 21, and 22, 1950, Monday through Wednesday noon.

Northeastern Society of Orthodontists

The fall meeting of the Northeastern Society of Orthodontists will be held at the Shoreham Hotel, Washington, D. C., Nov. 6 and 7, 1950.

Southern Society of Orthodontists

The twenty-sixth annual meeting of the Southern Society of Orthodontists will be held at the Sherry Frontenac Hotel, Greater Miami, Florida, Nov. 15, 16, and 17, 1950. Extensive plans and preparations are being made for this meeting. It will be held under the direction of President E. C. Lunsford, of Miami.

FRANK P. BOWYER, Secretary.

Italian Convention on Stomatology

The twenty-fifth annual Italian Convention on Stomatology promoted by the A.M.D.I. (Italian Medico-Dental Association), affiliated society to the F.D.I., will be held from Sept. 26 to 30, 1950, at Stresa (Lake Maggiore).

Denver Summer Seminar

The Thirteenth Denver Summer Seminar will be held this year at the Park Lane Hotel, Denver, Colorado, July 30 through Aug. 4, 1950.

Pan American Odontological Association

A Plan for a Prize Essay Contest Among Undergraduate Dental Students

The Pan American Odontological Association announces a prize essay contest in 1950 among undergraduate students in the dental schools in North, Central, and South America. Each essay should be a discussion of ways to establish better Pan American relations in the dental profession, on a subject (title) to be selected by the author. An *award of one hundred dollars* will be paid to the author of the essay adjudged to be the most useful. That essay will be published in dental journals, after its presentation at the annual meeting of the Pan American Odontological Association in December, 1950. Each essay may be written in its author's mother tongue, under an assumed name, and presented to the Dean of the Dental School for transmission to *Dr. J. A. Salzmann, 654 Madison Avenue, New York, 21, N. Y.*, for receipt by him on or before *Sept. 30, 1950.* After selection of the prize essay, the Dean of the school to which the essay is accredited will be requested to identify the author for payment to him of the award.

J. A. SALZMANN, CHAIRMAN,
WILLIAM J. GIES,
HARRY M. SELDIN,
Committee on Prize Essay Contest.

American Dental Association

A communication from the membership department of the American Dental Association will be sent to all members of the American Association of Orthodontists, asking them to

confirm the fact that they wish their names listed in the new American Dental Association Directory as specialists in orthodontics. All members are requested to respond promptly upon receipt of the communication.

Northwestern University Dental School

The Department of Orthodontics of Northwestern University Dental School presented a three-day course in the analysis of malocclusion with particular emphasis placed on cephalometric radiography.

The course was held on June 26, 27, and 28, 1950. The faculty consisted of staff members and guest lecturers. It included technique of cephalometric radiography, tracing, evaluation before orthodontic treatment, evaluation of results of treatment, and the application of cephalometric radiography to functional analysis.

Attendance was limited to orthodontists.

Orthodontist Named Colorado's "Dentist of the Half Century"

In a special midcentury issue of *The Journal of the American Dental Association*, marking fifty years of dental progress, Dr. Henry Forest Hoffman, of Denver, was named Colorado's "dentist of the half century."

Dr. Hoffman's nomination for the honor was made by members of the Colorado State Dental Association for "notable contributions in the field of organized dentistry and public health service."

Dr. Hoffman was born in Bellaire, Ohio, and graduated from the Colorado College of Dental Surgery in 1898. Since 1913 he has specialized in orthodontics.

He has served continuously on the Denver public health council since its incorporation in 1925, and was one of the incorporators.

In 1911 Dr. Hoffman was a member of the governing body of the National Dental Association, predecessor to the American Dental Association, and he also was a former head of the state association.

Notes of Interest

Dr. Spencer R. Atkinson, orthodontist of Pasadena, Calif., was recently awarded a visiting professorship at the University of Merida. Dr. Atkinson was previously awarded the same honor from the National University at Mexico City and the State University at Guadalajara.

Barney C. Cooksey, B.A., D.D.S., M.S.D., announces the limitation of his practice to orthodontics exclusively at Taylor-Vaughan Building, 101½ North Travis, Sherman, Texas.

Philip L. Klein, D.D.S., announces the opening of his office at 13113 Ventura Blvd., Sherman Oaks, Calif., practice limited to orthodontics.

Dr. Howard Yost and Dr. James Weesner, Associate, announce the removal of their offices from the First National Bank Bldg. to 803 West Division St., Grand Island, Neb., practice limited to orthodontics.

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The AMERICAN JOURNAL OF ORTHODONTICS is the official publication of the American Association of Orthodontists and the following component societies. The editorial board of the AMERICAN JOURNAL OF ORTHODONTICS is composed of a representative of each one of the component societies of the American Association of Orthodontists.

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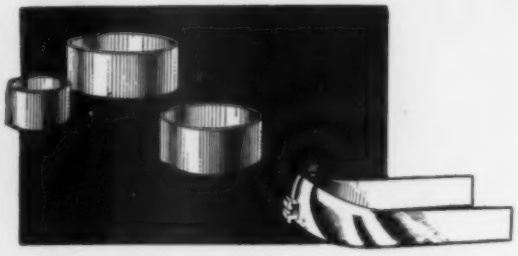

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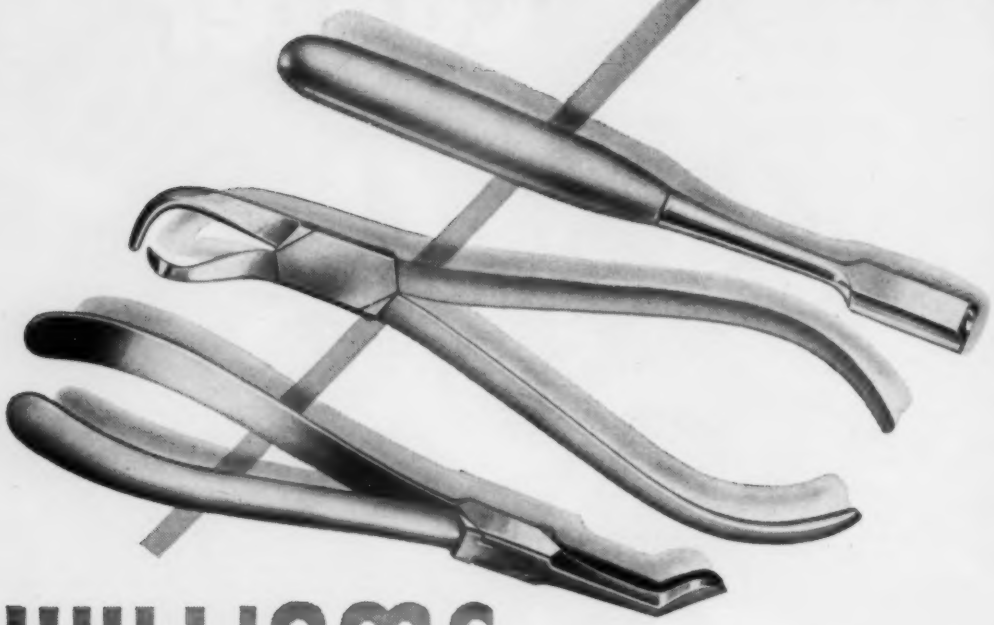

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